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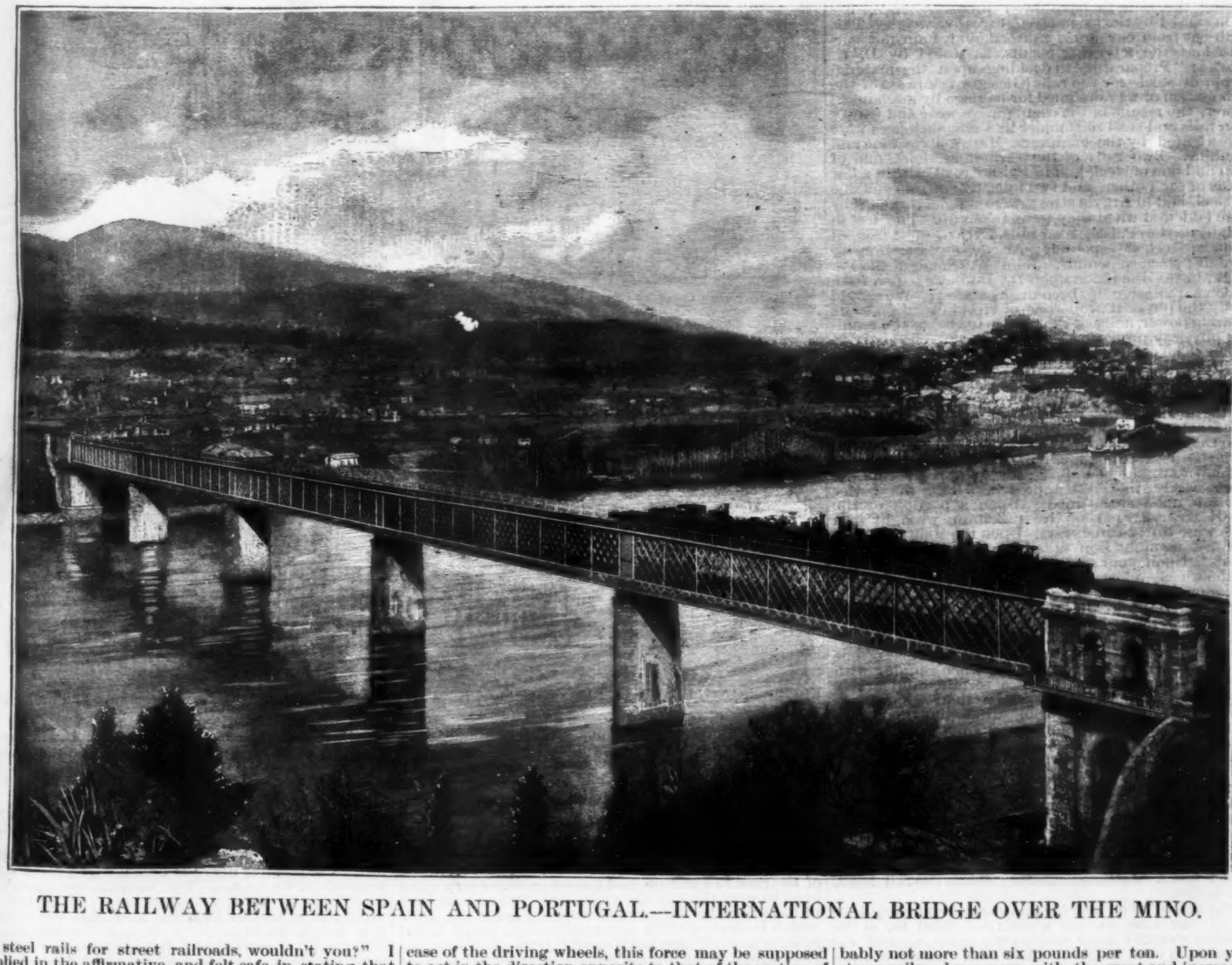
THE INTERNATIONAL BRIDGE OVER THE RIVER MINO.

OUR engraving shows the new railway bridge over the river Miño, on the International Railway between Spain and Portugal.

This bridge has a length of 1,300 ft., with two roadways, the upper one for cars being 78 ft. above the surface of the river. The piers rise 127 ft. from their foundations. There are five spans of iron, the three central spans being each 230 ft., and the two others 215 ft. each. Designed by P. Mancebo; built by A. Cazaux.—*Ilustracion Española.*



THE RAILWAY BETWEEN SPAIN AND PORTUGAL.—INTERNATIONAL BRIDGE OVER THE MINO.

WHAT IS THE BEST MATERIAL FOR STREET RAILROAD RAILS?*

By AUGUSTINE W. WRIGHT, C.E.

I WAS asked at a convention of the American Street Railroad Association, "You would recommend the use of steel rails for street railroads, wouldn't you?" I replied in the affirmative, and felt safe in stating that one steel rail would outwear *six* iron rails. I spoke from my experience upon steam railroads; but this question turned my thoughts to that subject, and to-day I would hesitate to recommend steel for street railroads. The requirements of a rail upon a street railroad and upon a steam railroad are quite different, and the experience of the steam road is of little benefit to the street railroad. Upon the latter, as usually constructed, the rail is provided merely as a wearing surface. My tracks are constructed as follows: Cedar cross-ties, seven or eight feet long, as the case may be, six inches thick, with face not less than six inches, are spaced four feet between centers. Upon them stringers are laid lengthwise of the road, from twelve to thirty feet in length, five inches wide, and seven to twelve inches in depth, as may be determined. The cross-ties are securely tamped with iron bars. The stringers are likewise tamped hard between the cross ties. The road, therefore, has a continuous timber bearing upon the earth. All that is required of the rail is to furnish a wearing surface to protect the said timber structure.

Steam railroads, as ordinarily constructed, use the rails as girders, to carry the weights superimposed from bearing to bearing, *i. e.*, from cross-tie to cross-tie. They must be strong enough when the head is worn out to carry this load. Thus far the requirements of the two systems are entirely at variance. Now for the wearing effect of the traffic. In what does it consist? Dr. Dudley, the accomplished chemist of the Pennsylvania R.R., has advanced a theory. It has been much discussed. Allow me to quote Dr. Dudley, who, upon "The Wearing Power of Steel Rails," said: "The forces that act between the top of the head of the rail and the wheels in rolling friction may, it seems to me, be regarded as two in number. There is first a force acting directly downward, due to the weight of the locomotives and cars. This force may be regarded as a vertical force acting perpendicularly to head of the rail, and is in action both when the train is standing still and when it is in motion. Secondly, there is a force acting parallel to the head of the rail, due to the traction or impelling power of the locomotives. In the case of the driving wheels, this force may be supposed to act in the direction opposite to that of the motion of the trains. . . . In the case of the drivers, the amount of this force, acting parallel to the head of the rail, is sufficient to overcome the total train resistance; in other words, to cause the train to move. In the case of the other wheels of the train acting individually, this force acting parallel to the head of the rail is small, being only that necessary to overcome the journal friction. The force parallel to the head of the rail acts only when the train is in motion. . . .

"Returning for a moment to the conception previously mentioned, that the top of the head of the rail and the surface of the wheel are a rack and pinion with infinitesimal teeth, but without regularity in the teeth, let us see what kind of a strain would be produced in these minute teeth by a force acting diagonally to the line of the head of the rail. I hardly see how we can avoid the conclusion that this strain would be a bending strain. . . . If we are right in regard to the nature of the surfaces involved in wear and the strains produced, wear is simply the breaking or pulling off of the infinitesimal teeth by the strains to which they are subjected. And here we see why it is that the softer rails give the better wear; for the harder the steel, the more brittle it is; and the more brittle the steel, the more readily will these infinitesimal teeth be broken off by the strains applied."

A Pennsylvania engine for passenger service, Class K, weighed in working order 96,700 lb., of which 32,900 lb. was on the forward drivers. Our worthy vice-president, Mr. Chanute, made some experiments upon the Erie Railroad. He found that a driving wheel five feet in diameter bore upon the rail head a space not greater than the thickness of a knife blade—about one-quarter of a square inch. Ten thousand pounds being the weight upon this driving wheel, the static pressure equaled 40,000 lb. per square inch. THIS is the great force coming upon steam railroad rails! It is to stand up under the locomotive that the rails must be designed. It is the locomotive that does the damage, and makes the greatest wear upon its rails. *Now this force does not exist* upon a street railroad. All the rail has to do is to resist the wear coming from journal friction, and, as stated by Dr. Dudley, it is very small. The journal and flange friction at six miles per hour is probably not more than six pounds per ton. Upon your steam railroad you now, with the great and increasing weight of your locomotives, need a *stronger* substance than iron, and this steel is.

I have used the words iron and steel. What do they mean? It is the same as if I spoke of wood or stone. There are many varieties of both, possessing very different qualities as to hardness, strength, etc., etc. Iron, when chemically pure, is one of the elements. Its atomic weight is 56, but it is doubtful if it occurs native. Its *ores* are very numerous, and they vary greatly in quality. In speaking of "iron," therefore, I mean the ordinary commercial article known by that name, and of average quality and workmanship. A certain addition of carbon changes the appearance and quality of the product. Thurston states: "Steel is variously defined by acknowledged authorities, and the metals known in the market and to the trade as steel cannot be completely and satisfactorily classed under any definitions yet proposed. The term includes, as formerly accepted, all impure irons which, in consequence of the presence of other elements, have the property of hardening by sudden cooling from a high temperature and of taking a definite 'temper' or degree of hardness by a definite modification of temperature,

* Read May 5, 1885.

and which may also be forged. It has been recently proposed to define steel as a compound, consisting principally of iron which has been rendered homogeneous by fusion; still another definition is iron recarbonized." An iron rail is, as it were, made fibrous by the process of rolling. A steel rail is homogeneous and not fibrous. The iron rails upon steam railroads failed chiefly by lamination. Louis Nickerson wrote: "Lamination is the result of some natural and determined law, and that law is this:

"That all material, when subjected to pressure, laminates in planes perpendicular to that pressure."

This law was announced by Prof. Tyndall after his experiments upon lamination. Ure's Dict. of Man. and Mines does not agree therewith. It states: "Careful examination convinces the writer that whenever lamination of the rail becomes evident, it can be traced to the imperfect welding together of the bars of which the rail is formed." And again: "An objection has been urged against malleable iron rails on the ground that the weight of the wheels rolling on them expanded their upper surface and caused it to separate in thin laminæ. In many of our large stations rails may be frequently seen in this state, layer after layer breaking off; but this may be regarded rather as an example of defective manufacture than anything else."

Holley & Colburn wrote: "Rails rarely *wear* out. They laminate or crush in the majority of instances." This applied to *iron* rails. Ashbel Welch, chairman of a committee, reported to the Am. Soc. Civil Engrs., May, 1875, upon the subject of rails, from which I extract: "The chairman of the committee was so much surprised at so little difference in the loss of metal in iron and steel rails, that since the former report was presented he made further examinations. . . . The average loss of metal per annum was, in the steel, 0·29; in the iron, 0·325 pound per yard. This shows that if iron was perfectly welded and as hard in the middle as at the top, and never loaded so as to crush or condense the metal (say not over 25,000 pounds per square inch), it would wear nearly as long as steel."

It would appear from the above quotations that the cause of failure of iron rails upon steam railroads, supposing the rails to have been properly made, has been caused by the locomotive's excessive weight. This is absent from our horse railroad, and I am not surprised at the following results, as stated by D. K. Clarke: "Preparatory to deciding upon the material —iron or steel—for the rails (Glasgow tramway) of the new system of way designed for haulage by mechanical power, the results of the comparative wear and tear of iron rails and steel rails under like circumstances were investigated by the engineers, Messrs. Johnstone and Rankine. Two rails of the earliest sections, one of iron and one of steel, laid in Paisley road, within a few yards of each other, and two rails, one of iron and one of steel, laid in Argyle street, were weighed when they were laid and when they were taken up. The loss in weight of the Paisley road rails, 7 years, was: iron, 44 pounds; steel, 43½ pounds: Argyle, 6 years: iron, 39 pounds; steel, 33 pounds. John W. Cloud, of the Pa. R. R., in the discussion upon Dr. Dudley's paper, from which a quotation has been made, stated: "We should study the physical properties of steel in relation to its wearing power, and ask the makers to give us the requisite physical properties, and leave the chemistry to them. The evidence that softer steel does give greater wear in rails is conclusive. At Altoona, careful examinations have lately been made of locomotive tires, and from one to two inches difference have been found in the diameters of the tires of wheels upon the same axle. Invariably, when these two tires are put into the lathe, it is found that the tire the most worn is the hardest. Iron glides imperceptibly into steel, it is difficult to fix the boundary; and it appears that the more nearly the steel approaches iron, the better the rail upon steam roads. Upon a portion of the Great Eastern road of Great Britain, wrought iron rails were thirty-three years! Upon the Montreal street railway, wrought iron rails have worn twenty-three years. Upon your steam railroad, the coning given to the wheels allows only a very small surface to come in contact with the rail head. Mr. Forney, in his paper "Rail Sections and Flange Wear," states that the load thus brought upon the rail head is from 40,000 to 60,000 pounds per square inch. The *Railroad Gazette*, Nov. 28, 1884, states that "a cast-iron car wheel of one of the patterns now largely in use, when running with its flanges against the side of a certain rail, largely used, has a cross bearing of no more than $\frac{1}{16}$ inch in extent. The area of the bearing surface under a 33 inch wheel in such case is ⅛ square inch. With the surfaces between wheels and rails no greater than they now quite commonly are, the weight borne by the opposing surfaces is in case of a fully loaded eight-wheel twenty-ton car about 60,000 pounds per square inch."

A prominent manufacturer of car wheels tells me that he gives a slope or cone of ⅛ inch in four inches upon his steam car wheels, and $\frac{1}{16}$ inch in two inches for the street car wheel. My stringer being dressed to pattern, I give its top such an inclination that my car wheel has a *continuous* bearing across the rail head, two inches.

The weight of an average American street car is 4,700 lb., or say 1,200 lb. per wheel; and 6,000 lb. is the greatest weight I have ever known upon a street car wheel from dead weight and live load. As the bearing is say $\frac{3}{16}'' \times 2'' = \frac{3}{8}$ of a square inch, and the load 6,000 lb., it equals 16,000 lb. per square inch, or about two-thirds the weight Mr. Welch considers necessary to condense or crush an iron rail.

The speed upon your steam roads is an important factor in the wear of rails. The speed upon the horse railroad does not usually exceed six miles per hour. I have tried to find experiments upon the relative abrasion of iron and steel. Rennie's experiments indicated that dry surfaces were abraded by the following weights in pounds per square inch: Wrought iron on wrought iron, 560; wrought iron on cast iron, 709; steel on cast iron, 672. Our car wheels are chilled cast iron. It would appear from the foregoing experiment that the iron rail would require five per cent. greater pressure than the steel to have abrasion begin. Our rails are *ground out.* If of fair workmanship and quality of iron, the weight is not sufficient to cause lamination; they must then fail from wear. The mud that covers our streets nine-tenths of the time affords a grit of greater or less sharpness, and the constant grind cuts off the rail's surface. The constant grind also tells upon our car wheels. The manufacturer who furnishes our wheels makes a wheel for steam roads that he guarantees to run 60,000 miles. Increased speed and the more general use of air-brakes, etc., etc., has caused this guarantee to be now reduced to 50,000 miles. The same metal and equal care in the manufacture give us a wheel whose average life, as nearly as I can compute it, is about 30,000 miles, upon a time table of *six miles* per hour! And this is a longer service than we have obtained from the wheels of any other manufacturer. Human life is not endangered by the breaking of a street car wheel, and we wear them much thinner than could be done on any steam road. We have had wheels taken out of our cars with the tread worn through, excepting $\frac{3}{16}$ of an inch.

My experience does not give the relative durability in practice of steel and iron rails. I have iron rails in our main line on Wells street. They are yet in fair condition after nine year' wear, but it it impossible to give the tonnage they have carried. I could give the number of car wheels that have passed over them, but not the general traffic or weight of passengers. I have steel rails in nearly as good condition under about the same tonnage. The time of service has been less, but the traffic greater. On the other hand, upon our Clark street main line, between Chicago avenue and the Viaduct, I had to take up the steel rails, equal in length to about two and a half miles, after four years and ten months' service. Our rail is denominated a "step rail." The car wheel travels on a head two inches wide on one side, and a tram three inches wide is provided for ordinary vehicles. About one-half the metal in the rail is in the head, which is one inch above the tram, but there is a groove in the tram $\frac{3}{16}$ of an inch deep. My car wheel flange is one-half inch in depth, and I have worn iron rails until the flange split the rail. The steel rails in question weighed originally 169,100 pounds; when taken out, 137,590 pounds,—a lost of about 19 per cent., or say 5 per cent. per annum for the entire rail. The greater loss was in the head, and a number of heads I measured at random had worn down a half inch. These rails are fastened to the wooden stringer by countersunk head spikes ½" × ½" × 5", twenty-two and a half inches apart. It is a wretched fastening, and does not prevent vibration. At the joint I now use a patent fastening, as described in a former paper, with satisfactory results. The vibration of the rails in question had caused nearly every spike head to wear through the tram, and there was no way of fastening the rails, unless a special spike was made with a larger head and new countersinks bored in the rails, or entirely new holes bored intermediate between the original holes; for the municipal authority will not permit the spike head to project above the tram, as it would interfere with ordinary vehicles traveling upon the tram. One end of each rail *against the traffic* was battered. I got an estimate of the cost of cutting off this end and boring new holes, when the rail might have been again used. Old iron is in constant demand, and many inquiries are made for it. Not so old steel. No one ever solicited our old steel. I wrote to various parties. One offered $10 per ton, another $12.50, and I finally sold them for $12.75 per ton f. o. b. to a party who expected to use them in the track in a country road. I could have sold them far more readily and at a price 25 per cent. to 50 per cent. greater had they been of iron. I would state that these rails wore quite uniformly, not developing any imperfections of manufacture. At certain hours eighty cars pass over that portion of my line in *sixty minutes*, besides many vehicles whose number I cannot approximate.

The first cost of iron and of steel rails is now the same, and unless the steel wears enough longer to make up the difference in value as "old scrap," iron is the cheaper. I brought up this question of relative durability at the last convention of the American Street Railroad Association, but obtained little information. If I had steel rails side by side with iron rails, and one wore twice as long as the other, it would simply prove the relative durability of that steel and that iron. To judge intelligently, I must know the chemical constituents and the process of manufacture. Comparatively poor iron can be made into fair rails if thoroughly welded, and good steel can make poor rails if improperly rolled. We all know that iron may be good or bad, and steel the same.—*Jour. Asso. Eng. Societies.*

A TORPEDO BOAT AT PARIS.

AFTER the battles of Fou-tcheou and Shei-poo, and on the eve perhaps of a still greater conflict in which the navy will play the principal part, the passage of a torpedo boat to Paris could not fail to excite the ever alive curiosity of the capital's inhabitants. The object of this voyage is not exactly to offer an attractive spectacle to Parisians of leisure, but to make an experiment that will permit of ascertaining whether the shipyards of the north could in case of need communicate by internal routes with our great Mediterranean military port. In time of war, granting that our flag were driven from the English Channel and the Atlantic, these shipyards would concur very efficiently, then, in the defense of the southern coast. The torpedo boat "68," which came to Paris from Havre by the Seine, stopped at Saint Denis to be provided with cork planking so as to reduce her draught. She is now anchored below the Royal Bridge, where she will remain for a few days. Then she will continue by the Seine, the Burgundy Canal, the Saone Canal, and the Rhone, as far as to the port of Bouc, from whence, by sea, she will reach Toulon, her tying-up place. She will stop at Laroche, Saint Jean de Losne, and Lyons. We doubt not that her commander, Lieut. Martel, will have to protect himself all along the route against the invasion of the curious. His amiability is great, but his boat is small, and he can only admit to it a few privileged persons.

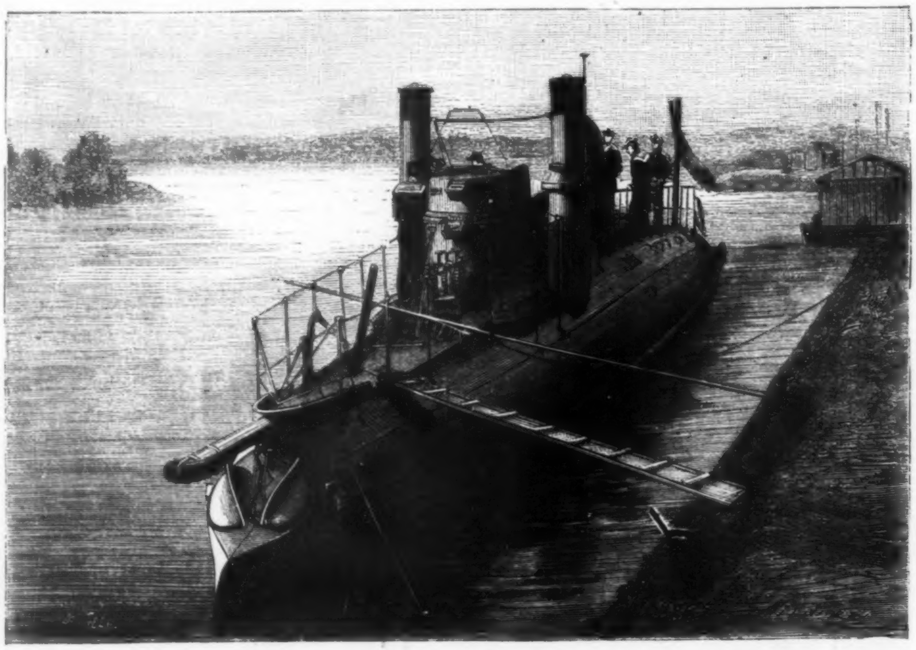


FIG. 1.—TORPEDO BOAT "68."

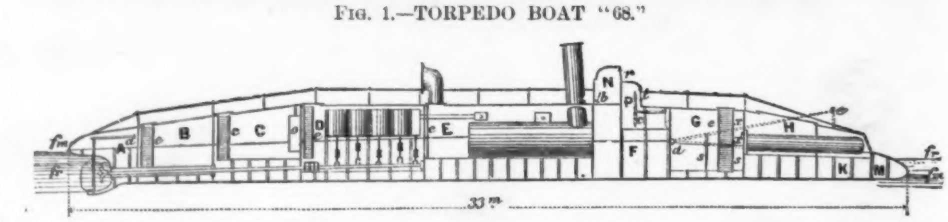


FIG. 2.—LONGITUDINAL SECTION. (*fr, fr.* Water line when at rest. *fm, fm.* The same when under way.)

This vessel was begun in August, 1884, in the shipyard of Mr. Aug. Normand. She is a coast torpedo boat, designed more especially for the defense of ports. Her total length is 108 feet and her breadth amidships is 10¾ feet. Her greatest depth of hold is 6 feet, but a superstructure of from 4 to 4½ feet increases by so much the height of the living compartments. At anchor, the water line is parallel with the keel; but when underway the latter rises in front, and the difference in draught is about five feet. When loaded, her displacement is 49 tons. In this weight the hull enters for 18·3 tons, the engine for 5·1, and the boiler for 7·7. The load, then, enters for 18 tons, or 36 per cent. of the total displacement. This small ratio will be understood when we consider that the boat is one in which everything is sacrificed for speed, that is to say, the engine.

The engine is of the compound type, with three vertical cylinders. It develops a power of 330 horses. The boiler is of the locomotive pattern, with direct flame, and is registered at 18 pounds. It consumes 880 pounds of coal per hour and per square meter (1·196 sq. yards) of grate when operating under a forced draught—the pressure of the air being 6 inches. All parts of the engine are of forged steel. The speed obtained on trials has been 20·9 knots, that is to say, 23 miles per hour. In service, 18 to 19 knots will be counted on.

We give herewith a general view of the vessel at anchor (Fig. 1) and a sketch of her longitudinal section (Fig. 2). In this section it will be seen that the hull is divided into 10 water-tight compartments. The hind compartment, A, contains the rudder bar and a certain number of barrels of fresh water. Compartment B is reserved for the second master and three quarter-masters, and compartment C for the captain.

This latter compartment contains a 150 gallon reservoir of water, O. D is the engine room. This contains the motor, the machine for the turbine of the surface condenser, the donkey engine for feeding the boiler, the engine for driving the blower, and a reservoir of water for the boiler. The boiler room, E, contains the generator, the coal bunkers (containing 6·5 tons of coal-cake), and the blower. The following compartment, N.P.F., is the launching room. The captain stands in the house, N, and, by means of a lever, b, launches the torpedo. The pilot is in front of him, at P, where he maneuvers the wheel, c, whose chains run to the stern and are there connected with the rudder bar, a. Sight-holes, r and t, permit of seeing outside and of steering properly. At F is a room for two reserve-torpedoes. The crew's apartment is in G. There are eight men in the crew. At H, K, and M are three cook-rooms traversed by the two launching tubes. These latter are placed symmetrically each side of the axis of the vessel, and their mouths, which are open at the moment of action, are closed ordinarily by a cover.

The torpedoes with which the "68" is armed are of the Whitehead type. The Whitehead and Luppi's torpedo is fusiform. It is 14 feet in length, and carries in front a charge of guncotton which ignites at a shock. A Brotherhood compressed air engine gives it the proper velocity of from 10 to 12 knots. It is launched by a small change of powder placed in the bottom of the tube. These weapons (of which there are four—two in the tubes and two in reserve) are maneuvered by means of a small movable railway, d, x, e. When the car which receives the torpedo is at the bottom of the incline, the part, d x, which pivots around the point, d, and is guided by slides, s s, is lowered so as to come opposite the tubes, and the torpedo is then pushed in and the breech is screwed on after a charge of powder has been put in.

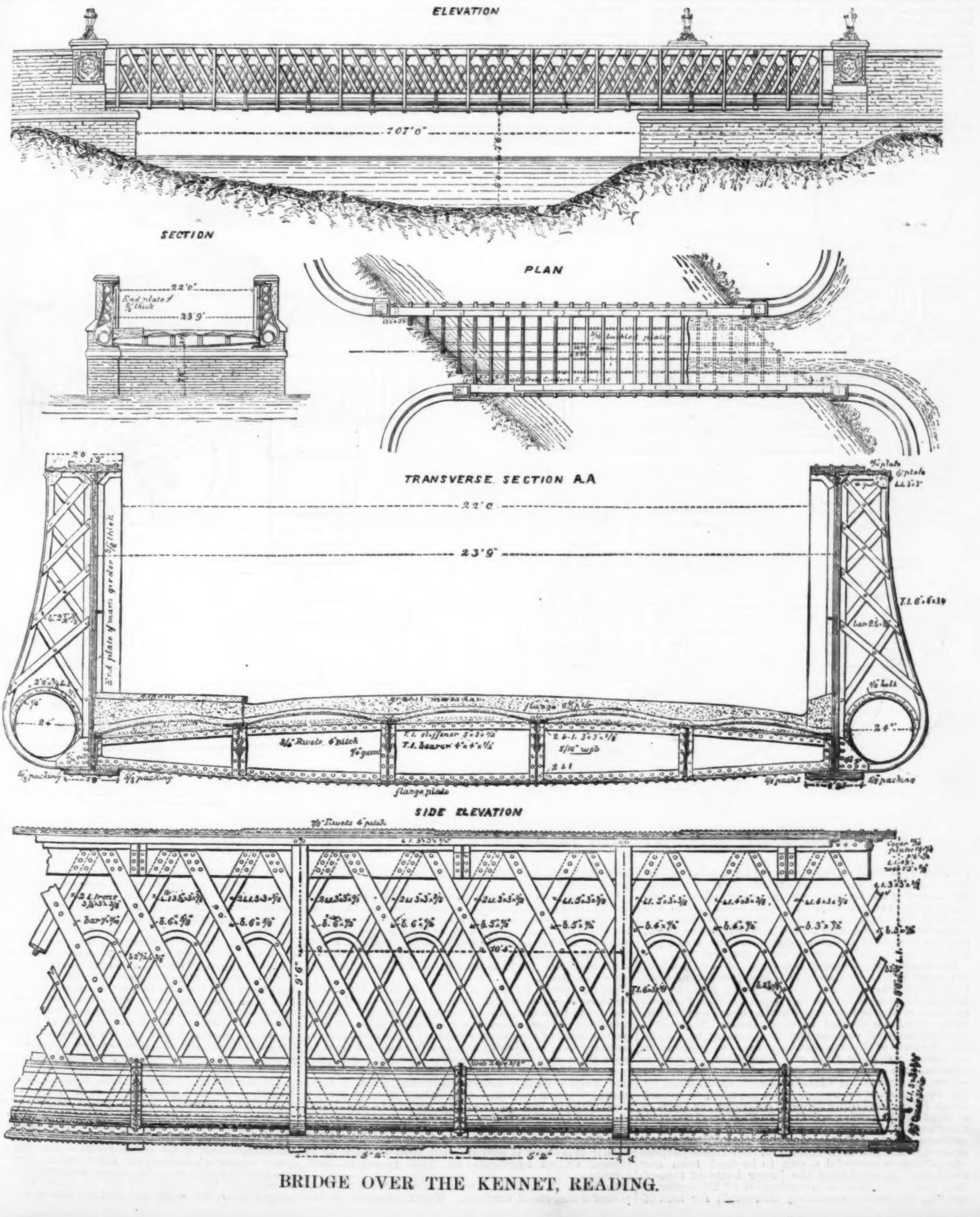
When the boat is under way, all the ports and other openings are closed, and nothing can be seen above deck but the captain's house, the smokestacks, and the air funnel; the tubes are closed, and the captain launches his torpedoes at the moment he judges opportune. These latter are fired like projectiles, dive as soon as they touch water, and, thanks to their own machine, make their way toward the point to be attacked. An immersion regulator, which is the important part of Messrs. Whitehead & Luppi's patent, keeps them, according to circumstances, two or three yards beneath the surface.

The object in giving torpedo boats great speed is to allow them to make a sudden attack, and especially a prompt retreat as soon as they have discharged their tubes. As they oftenest present their prow to the enemy, their engines are protected by five thicknesses of iron plate against the Hotchkiss balls. Such protection, however, is not always efficient, and counts for nothing against the fire of light artillery. Specialists are as yet divided upon the question as to the power of torpedo boats. It is redoubtable, although the present arrangements of ironclads often render it illusory; but it is always ephemeral, and at the mercy of the least fortunate cannon shot. We believe that we echo the general opinion of the French navy when we accord it but a moderate importance in the combats of ironclads.

The torpedo boat "68," like all similar vessels, is of steel. The upper works and carapax are one-fifth inch thick. The boat cost about 50,000 dollars. The torpedoes that it uses cost from 2,000 to 2,400 dollars each. These, as may be seen, are expensive projectiles. If we reflect, besides, upon the deceiving nature of their action, we shall find that these vessels, endowed with prodigious speed, and these projectiles, provided with screws, constitute the most costly of the maritime apparatus of war.—*La Nature.*

NEW BRIDGE, KENNET RIVER.

THIS bridge has been erected over the Kennet, at Reading, near its mouth adjoining the Thames, by the

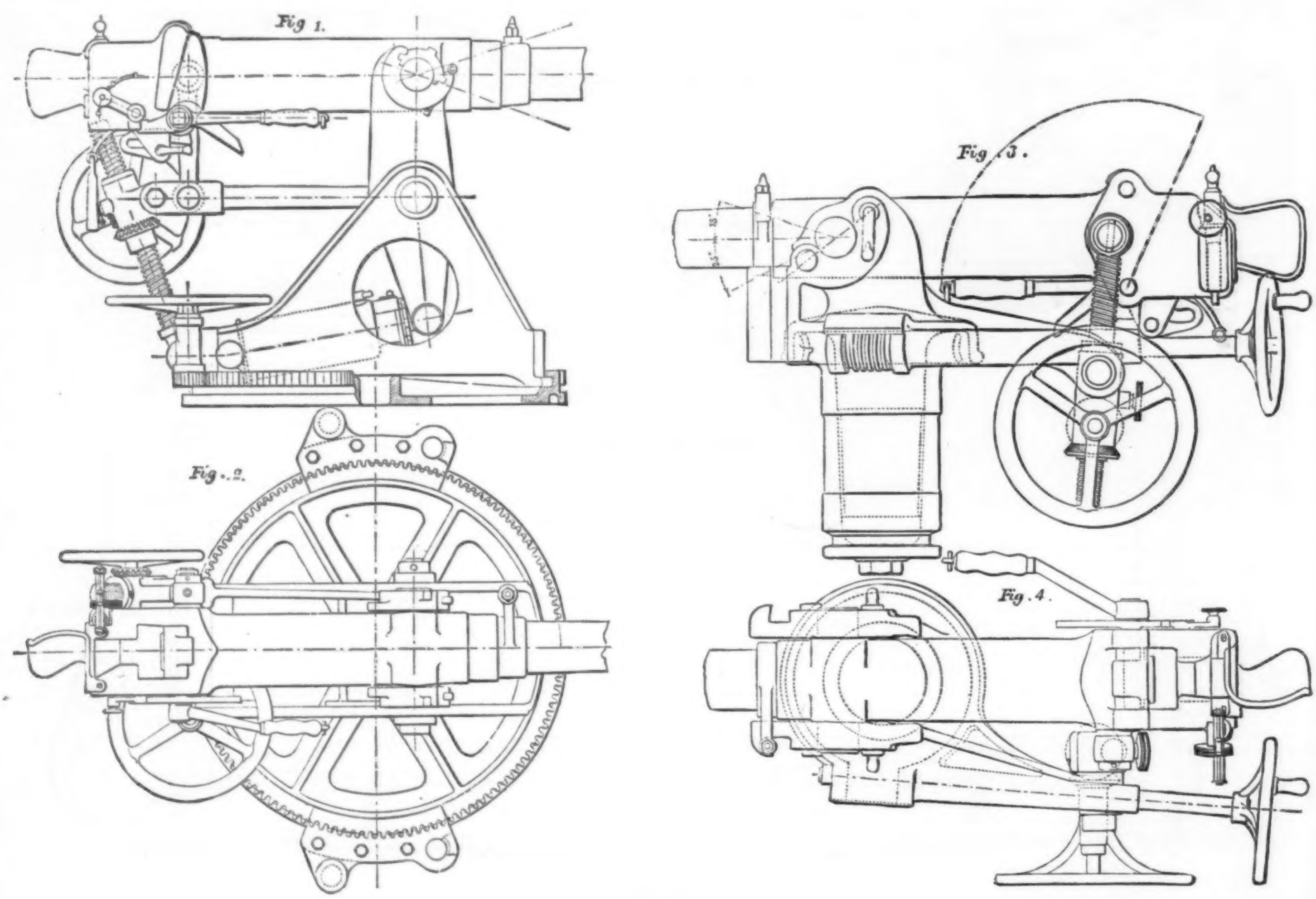


BRIDGE OVER THE KENNET, READING.

Reading Gas Company, for the purpose of connecting its works with a new site of about 13 acres, and for carrying the necessary mains from the present to the new works. The bridge is on the skew at an angle of 42°, and the span between the piers from center to center is 107 ft.; the main girders are 119 ft. 8 in. long and 9 ft. 6 in. deep, the top booms being 2 ft. 6 in. wide and the bottom booms 1 ft. 9 in. wide and 23 ft. 9 in. apart, center to center, giving a clear way over the bridge of 22 ft. The cross girders are 2 ft. deep at the center, placed 5 ft. 2 in. apart, on the top flanges of which are riveted the wrought iron buckled plates, which have a rise of 3 in. in the center, the longitudinal joists being supported on T-iron bearers. The ends of the main girders rest upon Bessemer steel rollers and cast iron bed plates planed on the surface. It will be observed that two 24 in. mains, which are of wrought iron with flanged joints, are carried outside the main girders by the stiffening brackets in order to give the regulation height over the river without increasing the level of the roadway of the bridge more than necessary. These mains are loosely laid upon the webbing of the stiffeners, and are free to move with the expansion or contraction of the bridge or with the slight vibration of a passing load, and each main is provided with an expansion joint on both sides of the bridge. In practice these mains are thoroughly gas tight—not always attained on bridge work—and are, of course, at all times exposed to view. The lattice bars and various other parts are of the various dimensions figured on the detailed drawings. The bridge has been erected from the specifications and plans of Mr. Edward Baker, by Messrs. Handyside & Co., of Derby.—*The Engineer.*

THE NORDENFELT MACHINE GUNS.

AT the Inventions Exhibition, London, the exhibits of Mr. Thorsten Nordenfelt occupy a very prominent position with what at this time calls for special attention, viz., a most interesting exhibit of a number of his now well known and very generally adopted machine guns, ranging from the $2\frac{1}{4}$ in. 6-pounder to the smallest and lightest mitrailleuse in existence, his single barrel rifle caliber gun, which weighs but 13 lb., and yet is capable of discharging some 180 shots per minute, which are thus described in *Engineering:*



NORDENFELT GUNS AT THE INTERNATIONAL INVENTIONS EXHIBITION, LONDON.

We would call particular attention to the Nordenfelt 6-pounder here shown, as it is at present the most powerful machine, or rather quick firing gun, in the field, and because a type of this weapon, also a 6-pounder, has recently been adopted for the naval service, but as the order was divided between Messrs Nordenfelt and Hotchkiss, it was considered necessary to assimilate the guns of these inventors as near as possible in all ballistic details; thus our Nordenfelt 6-pounders have only an initial or muzzle velocity of 1,830 feet per second, as against the muzzle velocity of 2,130 f.s. for the 6-pounders of the same system supplied to Brazil, Italy, Japan, and other foreign countries, as well as some of our Australian colonies. In Figs. 1 and 2 there is shown the Nordenfelt 6-pounder mounted on its recoil carriage, a system of mounting peculiar to this 6-pounder, and which has been devised for the express purpose of enabling so powerful a gun to be fired from any ship's deck, or even from the larger boats of men-of-war, thus obviating the complication of fittings by requiring one class of mounting (non-recoil) for men-of-war and another class (recoil) for merchant steamers, boats, etc. The weapon recoils only some 4 in., and its aim is in no way thrown out by the recoil, but once laid for a fixed target it can be fired several times as rapidly as possible without altering its original direction; by this means a series of very rapid shots can be discharged, fresh aim being taken after each series.

There is also to be seen a very pretty model of the Nordenfelt 6-pounder, mounted on its recoil carriage, on a stand representing the side and port of a man-of-war; this model is a special design of Mr. Nordenfelt's for reducing the size of a ship's 6 pounder port to a minimum, an important feature, both structurally and as decreasing the effect of rifle fire on the guns' crews when the ports are up, while this system of construction of port has a further advantage in allowing the stowage of these 6-pounders inboard in a very small space when they are not actually needed at sea or in harbor.

There have been some experiments recently made at Portsmouth with the Nordenfelt and Hotchkiss 6-pounder service guns to test the effectiveness of the two systems of mounting, and the results most conclusively showed the superiority of the hand wheel and screw training and elevating gear introduced by Mr. Nordenfelt for all his guns. The particulars of these experiments are as follows:

Nordenfelt 6-pounder (mounted on its recoil carriage) fired 186 shots in 22 min.; Nordenfelt 6-pounder (mounted on its non-recoil carriage) fired 186 shots in 20 min. This gives, for, the Nordenfelt 6-pounder an average rate of fire per minute of 9 shots, while the Hotchkiss 6-pounder only obtained an average rate of $5\frac{1}{2}$ shots per minute, or about half the rapidity of fire obtained under the same circumstances for the Nordenfelt 6-pounder and mounting. From these figures it will be seen that the recoil carriage slightly decreases the rate of fire, but its advantages are so general and important that this slight loss of speed is more than compensated for.

The great power of these new ship guns is exemplified by the following data obtained from the trials at Portsmouth with the Nordenfelt 6-pounder, muzzle velocity 1,830 f.s. At 600 yards at right angles it pierced a 3 in. solid steel plate; at 300 yards at 60 deg. angle to the line of fire, a solid steel plate 3 in. thick; at 300 yards at 15 deg. angle to the line of fire, a solid steel plate 1 in. thick.

We can hardly imagine a more effective armament for those of our merchant steamers which have been and are to be enrolled into the naval service, than a broadside of these quick firing 6-pounder guns, for they are the acme of simplicity combined with great power, accuracy, and rapidity of fire, needing but few men to work them, and being comparatively light. Take the case of five of these 6-pounders mounted on each broadside of a merchant steamer; this would mean a total weight of guns, carriages, and fittings of only some 8 tons, while in one minute each broadside could discharge at least forty-five projectiles, representing a weight of metal (for solid steel shot) of 270 lb., or in the case of steel or common shell, an explosion inside the hostile ship every $1\frac{1}{4}$ seconds, each shell discharging 25 pieces, or an aggregate of 1,125 pieces in each minute.

In Figs. 3, 4, and 5, we show the Nordenfelt 6-pounder non-recoil carriage. The mechanism is the same for all the shell guns of this system, and consists of only ten pieces in all. The extreme simplicity of this system of mechanism will be apparent from the following fact taken from the official report of a lengthened trial in Sweden with the Nordenfelt $1\frac{1}{2}$ in. gun; in this instance a Swedish naval officer took but one minute, counted from the time of firing one shot to the insertion into the barrel of another, to extract the fired cartridge, take out and to pieces the mechanism, put it together, replace it, and reload the gun. Of course this same operation could not be carried out in so rapid a manner in the case of the 6-pounder, because its mechanism is somewhat heavier, but the simplicity of manipulation remains the same.

These quick firing 6-pounder shellguns may be put to other work than that of a ship or boat weapons, as in Australia, where they are intended for the armament of isolated small works for the purpose of sweeping the approaches to the harbor, and covering the mine defense, and are so arranged that they may be readily moved from point to point, thus constantly opening fire on an enemy's fleet or ship from a new position.

We may here note that the rate of fire before mentioned does not represent the actual capability of the Nordenfelt 6-pounder in this respect, as when these 186 shots were fired the gun was mounted on the Handy, a small vessel used for gunnery experiments, which was pitching and rolling at the time with a very quick, lively motion, while the target aimed at was but a barrel with a flag hoisted on a staff, the range 1,000 yards, and the aiming as deliberate and careful as possible (as was proved by the fact of a shell from the Nordenfelt 6-pounder knocking the flagstaff away); at Portsmouth, previous to this experimental firing, an officer of the Excellent fired three series of six shots each with a maximum time of 16 seconds and minimum time of 14 seconds for each six shots, or at the average rate of 24 shots per minute.

The Nordenfelt 6-pounder (and other shell guns) may be fired either automatically (when very rapid fire is necessary) by the gunner who works the lever for loading and extracting the empty cartridge cases, or at will by the gunner who aims the gun by the pulling of a trigger.

The next Nordenfelt shell gun shown is the 1·65 in. $2\frac{1}{2}$-pounder mounted on a naval cone; this is a most useful weapon where an intermediate quick-firing machine-gun is required between the more powerful 6-pounder and the anti-torpedo boat guns for the purpose of boat armaments or for service on shore. For its size this is a very powerful weapon, having a muzzle velocity of 2,008 f.s., and being capable of penetrating $2\frac{1}{4}$ in. of wrought iron at 1,000 yards. Between the 6-pounder and this $2\frac{1}{2}$-pounder, Mr. Nordenfelt constructs also a 4-pounder and 3-pounder with respectively a muzzle velocity of 2,095 f. s. and 2,067 f. s.

The weapon illustrated at Figs. 6 and 7 is the Nordenfelt magazine quick-firing shell gun of $1\frac{1}{2}$ in. caliber, discharging a $1\frac{1}{2}$ lb. projectile, and specially designed as an anti-torpedo boat shell gun. The mechanism of this weapon differs from that of the other Nordenfelt shell guns to enable it to be used with automatic feeding, for which purpose an upper and lower hopper is provided, the latter being fixed to the gun during firing, and the upper hoppers being used to maintain the lower one full of cartridges. Each hopper holds five cartridges, and the rate of fire of this

weapon is about 60 shots per minute for a maximum, and 35 shots when deliberately aiming.

Its muzzle velocity is 1,580 f.s., and though it is a more powerful and effective weapon than the Hotchkiss 5 barrel 1½ in. gun, yet it labors under the same disadvantages as that weapon for the particular work of defending ships against torpedo boat attack, in that it can only discharge single shots, and not "volleys," as in the case of the anti-torpedo boat Nordenfelt 4 barrel 1 in. guns.

In this exhibit a 5 barrel 1 in. gun is shown which, with the exception of its greater rapidity of fire and its capability of discharging five steel bullets in each volley, is precisely similar to the service 4 barrel 1 in. gun. The rapidity of fire of these Nordenfelt 1 in. guns is for the 5 barrel, in one minute, maximum 240 shots; with deliberate aim, 100 to 150 shots; and for the 4 barrel, in the same time, maximum 200 shots; with deliberate aim, 80 to 100 shots.

There are also exhibited by Mr. Nordenfelt two kinds of machine guns for the armament of torpedo boats and torpedo-boat hunters; one a light 1¼ in. shell gun, discharging a 14½ oz. shell projectile with a muzzle velocity of 1,540 f. s., and the other a 2 barrel 1 in. gun with the same ammunition as for the 5 barrel and 4 barrel guns, but with the new form of Nordenfelt mechanism, which we shall explain in connection with the 5 barrel rifle caliber gun. The 2 barrel 1 in., as compared with the 1¼ in. shell gun, has the advantages of twice the rapidity of fire and the discharging of volleys each time the sights come on; but the latter fires shell projectiles. In our navy, and in the Italian, Brazilian, and other navies, the Nordenfelt 2 barrel 1 in. gun has been adopted for the defense of torpedo boats; and, looking to the fact that encounters between these craft will be usually carried out at short ranges, we feel convinced that in actual naval war in the future this system of torpedo boat defense will be found the correct one.

There is a capital sample case of the various Nordenfelt ammunition, suggesting for the larger examples great power, and for the small bore rapidity of fire and freedom from jams.

We now come to a consideration of the rifle-caliber machine guns, often termed mitrailleuses, exhibited by Mr. Nordenfelt, among which are included a 12 barrel, 5 barrel, 3 barrel, and single barrel. The former, with the exception of its greater rate of fire by reason of the two additional barrels, is precisely similar in all respects to the well-known 10 barrel gun of this system; this 12 barrel Nordenfelt, mounted on its field carriage with limber, presents a most workmanlike appearance, and impresses one with its deadly power, which is not belied in actual practice, as it has fired at the rate of 1,200 shots, or 100 volleys of twelve shots each, in one minute. The 10 barrel Nordenfelt has actually succeeded in firing 100 consecutive volleys of ten shots (1,000 shots) in 59 seconds, and 3,000 rounds in the incredibly short time of 3 min. 3 sec.

Two 5 barrel guns of this system are to be seen; the one with the new mechanism is mounted on the field carriage and limber, and the other is mounted on its tripod stand. The system of mechanism which has been recently introduced by Mr. Nordenfelt, and which we illustrate in Figs. 8 and 9, has the advantageous feature of exceeding simplicity, and does away with the overhanging of the action-block on the drawing back of the hand lever, as in the case of the original form of Nordenfelt mechanism.

In the construction of this gun the aim has been to make the mechanism as simple as possible, and at the same time easy to take to pieces and adjust. That the object has been successfully carried out will readily be seen at a glance. There is not a single screw, bolt, or nut in the mechanism proper, and every part can be taken out and replaced by one man by hand without the aid of a single tool. The parts, seven in number (besides one extractor, one hammer, one firing-pin, and one spiral spring for each barrel), which make together 27, or 5·4 parts per barrel, are ingeniously placed so as to bind one another together within the frame; the barrels are simply inserted through the center cross-piece and the front part of the frame, and are kept in their position perfectly steady by an eccentricity on the cover hinges. They are easily taken out by hand without the use of any tool whatever. The parts of the mechanism are called the carrier block, the plungers, the action block, the trigger comb, the action, and the hand lever. The action is as follows: The cartridges drop down from the hopper through openings in the cover into recesses in the carrier block, which is afterward brought over to the right so that the cartridges come in line with, and in the rear of, the barrels; they are then pushed forward into the chambers of the barrels by the advancing plungers; when they have fully entered the chambers the plungers have left the action block, which by a tail on the action lever is moved over to the right to bring the hammers in line with the plungers; then the same tail acts on the trigger comb, moving this also over to the right, thus releasing the hammers, which throw their blow on the firing-pins, causing them to strike the caps in and fire the cartridges. All this action takes place during the forward movement of the hand lever. The position of the parts of the mechanism at this moment is shown in the illustration. By reversing the movement of the hand lever, the trigger comb is brought back to its former position by the tumbler spring and the action block by the tail end of the action lever. Then the recesses in the action block for the plungers are in a line with the plungers, which now recede within them. When the plungers recede, the extractors, which with their claws gripe the rims of the cartridge cases, withdraw these empty cases from out of the chambers. The empty cartridge cases now fall out through openings in the carrier block. During the latter part of the backward movement of the plungers the hammers are cocked, and the carrier block is moved to the left to its first position to allow a fresh layer of cartridges to fall down. The hand lever is now pushed forward, and the loading and firing action repeated. The movement of the carrier block is produced by lugs on the plunger plate acting upon corresponding inclines on the carrier block. The movement of the plungers is produced by a friction roller on the action lever acting in a slot in the plunger plate.

We find this improved method also adopted for the 2 barrel 1 in., the 7, 5, 3, and 2 barrel rifle-caliber guns of this system. This Nordenfelt 5 barrel, by reason of its light weight (130 lb.), rapidity of discharge (360 shots in half a minute), volley fire (five shots in each), spreading motion, and simplicity of mechanism, seems a most effective rifle-caliber machine gun for general service; and such apparently is the opinion in our navy, as considerable numbers of them have been already introduced into the service and are now under construction. Moreover, this favorable opinion of the Nordenfelt 5 barrel is not by any means confined to our navy.

This is the machine gun that has been brought into such prominent public notice by the Central London Rangers, which corps have been the means of showing how readily this sort of weapon, when mounted on a limber or infantry carriage, can accompany a force on the march, and how easily it can follow the movements of the infantry it is attached to, when drawn by men.

Passing on to the 3 barrel, here we come to what must be treated as the smallest rifle-caliber machine gun practically admissible for actual service, either ashore or afloat; this Nordenfelt weighs only 56 lb., but yet possesses a volley of three shots, and a rate of fire of 400 shots per minute.

For mountain warfare or otherwise, where pack animals are required to convey the weapon, this light Nordenfelt may have its useful sphere of action, as in this case every pound of weight is an important consideration, but otherwise it requires nearly as many men to draw it as the 5 barrel, and one horse is needed for both weapons; while of course in every respect, except weight of gun, the 5 barrel is very considerably superior to the 3 barrel. There are two noticeable points in connection with all the Nordenfelt rifle-caliber machine guns of more than one barrel: first, they can be adapted to fire any kind of rifle ammunition, even the of late much abused, and deservedly so, Boxer cartridge; secondly, that the loading, firing, and extraction is independent for each barrel: so that if one or more barrels become jammed by any untoward cause, the remaining barrel or barrels can continue the firing.—*Engineering.*

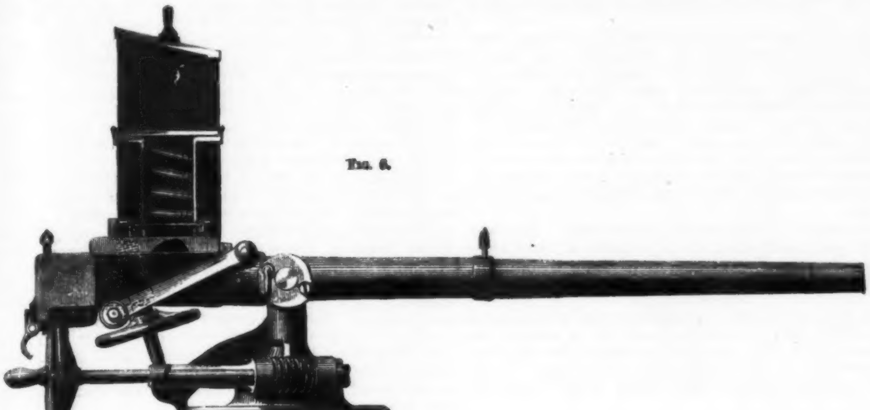


FIG. 6.

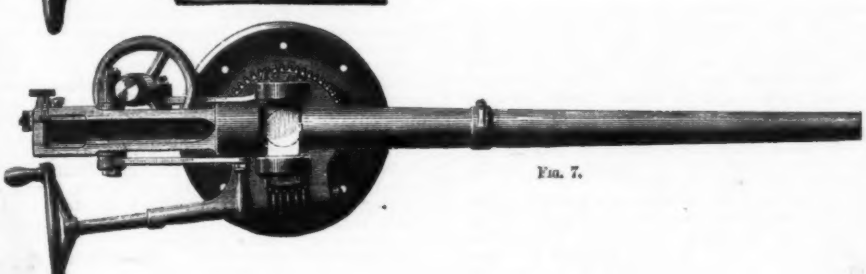
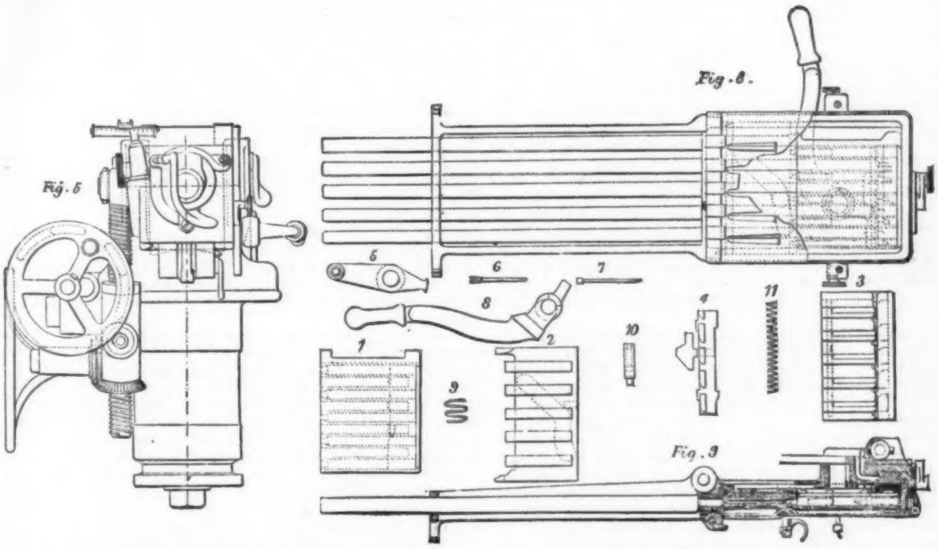


FIG. 7.



NORDENFELT GUNS AT THE INTERNATIONAL INVENTIONS EXHIBITION, LONDON.

WASTE IN COTTON MILLS.

PRINT cloth manufacturers say that they can only manufacture five and a half yards of cloth out of one pound of cotton. If this statement be correct, there is over twenty-one per cent. of a loss sustained on each pound of cotton while going through the process of manufacturing, as print cloth weighs out seven yards to the pound. This seems to be an enormous loss to sustain in manufacturing; and it is apparent to thinking men who have been brought up in the mills from childhood, that there is a way whereby a saving in waste can be effected. In the first place, more work is put upon each operative in the mills than they are able to perform—especially when the high speed machinery as driven as at the present time is taken into consideration; consequently, less quality to the quantity is obtained from the material going through the process of manufacturing than there would be if operatives were employed under more favorable circumstances.

It is often said by experienced operatives, who seem to possess a thorough knowledge of factory work and who have had experience in the mills, both in England and here, that more waste is made in one mill here than there would be in twenty there. As absurd as this assertion may appear, we will not attempt to deny it, for the waste, such as pulled cops, which is made in the weaving and spooling rooms in the cotton mills of this country is largely in excess of what it should be under wise, judicious, and practical management. Now let us try to discover the cause of the great quantity of waste made here, as compared with England, and place them before the eyes of manufacturers for consideration. It is true that in England, if only one cracked cop is made by a spinner, and sent into the spooling or weaving rooms, it is sent immediately back to him, and he is questioned as to the cause of it; but in our mills here, cracked and bad cops are sent in large numbers into the spooling and weaving rooms, and no complaints are made about them. Now the reason the spinner is not found fault with on this account is that the overseers and superintendents know that they have too many spindles to mind to make good work.

The spinner in America, as a rule, has to mind a pair of mules, no matter how long they may be, or how many spindles they contain, with a little back boy only as his assistant; and he, in many instances, has to tend the roping for two pair of mules, while in England a spinner on the same size mules will have a back boy and a young man piecer, and in some instances two piecers when the mules are large, to help him keep his mules in operation, and produce good work.

The mules here are run at a higher speed also for the same counts. In the Oldham district, England, the standard speed fixed on the list, which has been agreed to by the spinners and their employers, for spinning 32s twist, commonly called warp here, is three stretches in fifty seconds, and if a higher speed is run, there has to be an addition made on the regular list of prices; while there are mules spinning twenty-nine twist in many of our New England towns and cities, and running three stretches in forty-five seconds, consequently

the spinners in our mills, owing to the lack of sufficient help, and the high speed their mules are driven at, cannot make good work and keep them in operation the day through; hence the spooler and weaver have to suffer through being the recipients of bad and cracked cops, as alluded to above, and not having time to try and straighten them, owing to having so many spindles and machines to tend themselves, invariably tear them up, and thus they find their way into the waste bag.

The rule in England is to allow experienced weavers four looms to mind, and in most instances they too have a little boy or girl assisting them, commonly termed a tender; while young women in America mind eight print cloth looms alone; therefore, they cannot find time, and keep their looms in motion, to bestow the same care on the cops passing through their hands as the English weavers can.

These are points to which we desire to call the attention of the superintendents and manufacturers of the New England mills, to try and ascertain whether the policy they have practiced so long, of giving so many spindles and looms to one operative, is going to be the most profitable or not, in the end.—*Wade's F. and F.*

CANNED FOOD.

A MAINE correspondent furnishes to the *N. Y. Analyst* the following very interesting history, statistics, and description of canned food, as produced and packed in Maine.

"In 1850 Nathan Winslow packed corn at Westbrook, which was a year before I commenced in the business. In 1851 he packed again, and I worked for him, and he then bought his cans. In the winter of 1852, Mr. Winslow got a complete outfit, and began manufacturing his own cans, and manufactured about 30,000 the first year, and filled them all there at Westbrook. From that time the business has been going on, increasing from year to year. I do not think there were more than 60,000 cans packed in any one year until the beginning of the war. That gave it an impulse, and from that time to the present it has kept on increasing, until we have been able to pack 200,000 cases, or 4,800,000 cans, of corn in a single year.

"In the first place, when we first started, everything was very rude. We cut the corn from the cob by hand with a knife somewhat similar to a case knife, with a small gauge attached to it. It was done in that way until 1874, when we first began to work with a machine. We are now able to do as much with a machine and one man in a day as we could then do with twelve persons by the hand knife. The processes, the dies, and all our tools have undergone from time to time since then very great changes and improvements. They first began making cans by cutting out the round piece which forms the bottom with hand shears. Then they got a machine called circular shears, and the piece of tin was put into it and turned round and cut out in that way. Afterward, a die was used which cuts the tin right through, and cuts the piece out round. The next improvement was that, instead of punching the bottom out round and putting it into another die and turning up the edge, a machine was used which cut the bottom out whole and turned up the edge at the same time. Last summer, with the improved machinery, we were enabled to turn out 20,000 cans per day. In the old times we used to consider that, if a man made fifteen dozen cans per day, he was doing a good day's work. Now, with the aid of the machinery, a man will turn out sixty dozen per day.

"Early in the spring of the year the owners or operators of factories make contracts with the farmers to plant so many acres of corn, the packer furnishing the seed, the farmers being paid for the corn by the can. Upon an average, there is in an acre of corn about 1,500 cans, although we frequently get 2,000; 1,500 cans is about the average. The corn is taken from the field and brought to the factory in the husk. When it reaches the factory, the farmer is told where to deposit it; he leaves it, and the foreman of the factory gives him a receipt for it. A receipt is given for every load. The farmer expects to be credited upon the books with as many loads as he holds receipts. The corn is then husked by hand, and carried into the shop in separate lots. A card is attached to one of the baskets, stating how many baskets there are in the lot, and to whom it belongs. The corn is then taken to the cutting machines, where it is cut from the cob. It is then weighed and credited to the farmers, and is no longer kept by itself. After it is weighed, it is passed through a sieve, where every particle of husk, bits of cob, and everything except the pure corn is removed, and it is then put into the cans by means of a tunnel shaped machine, in which there is a plunger. A boy puts a scoopful of corn into the machine, a man holds a can under, and the plunger forces the corn into the can until the can is full. The can is then weighed, and if found too heavy, a little is taken from it, and, if found to be too light, a little is added, so that all cans shall contain the same in weight. The cans are then washed, the tops wiped, and then a little cap put upon the top, when it is ready for the sealer. It then goes into the sealing room, where a man with a patent sealer seals it. The old method of sealing was by using a hand copper. We now have a sealer which is round, and fits on over the end of the can. A little solder is then dropped on, and, with a little turn of the copper, the sealing is done. The cans are then taken to the bathroom and placed in large pans and carefully lowered into the kettles of boiling water, two pans, containing 81 cans, making one tier, each kettle holding 12 pans, or nearly 100 cans. If any of the cans are not sealed properly, the air bubbles from them, and they are taken from the kettles and mended. After the corn has boiled for a certain length of time, it is removed from the kettles, and the tops of the cans punctured, and all the steam and air escapes, and they are then soldered again and returned to the kettles and boiled again for a certain length of time, until the corn is thoroughly cooked, when it is taken out and cooled. They are carried into the open air, and water sprinkled upon them. The next morning, the cans are removed to the storehouse and spread upon the floor, in order that they may be thoroughly cooled and dry. If we find cans that are not perfect, they are taken out. When the cans are thoroughly cooled they are piled up, and wait until we are ready to label them. Then the first process is to clean them. After they are properly cleaned the labels are put upon them and they are put into boxes, each holding two dozen cans. The brand of the goods and the name of the packer are then stenciled upon the end of the box. We generally have three kinds of corn, although there may sometimes be more. The grades are distinguished by the quality of the corn. In the best quality, we put nothing but the corn in perfect condition. Great care is exercised in having the corn brought to the shop in proper condition, that is, when it is full in milk, and we have also to exercise great care in handling it after it reaches the factory to prevent its heating. For instance, we must not allow it to lie in piles too long. If we have any that is to remain for any length of time, it must be put into the sheds and spread. We allow just as short a time as possible between the time when the corn is husked and cut from the cob and sealed up and put into hot water, and we are very careful when we lower the pans into the kettles to have them boil as quickly as possible, and not allow them to stand, as if, for instance, the fires got low, and they were to stand in the water twenty or thirty minutes before the water reached the proper temperature to boil them. We intend to have the water in a condition so that when the cans are put into it they will begin to boil. There would be danger in allowing the cans to stand in the water for any length of time before it reached boiling heat.

"Succotash is packed in much the same manner as corn, except the difference in handling the beans. Lima beans are used. They are brought to us all shelled. We scald them, in the first place, in bulk. When they are scalded sufficiently, they are taken from the water and placed upon racks, where they dry and cool. We usually scald them at night, and allow them to lie until morning, when they are mixed with the corn in the proportion of two parts of corn to one of beans. The mode of packing is then about the same as that of packing corn.

"Peas are canned in about the same way. We buy them in the pod, and shell them ourselves; and they are then put into the cans uncooked, and are then put through about the same process as the corn and succotash.

"The packing of apples, pumpkins, and squashes is of recent origin, but in some seasons it is carried on quite extensively. The process is much the same as before described, except a difference, of course, in the manner of cooking, and in that much larger cans are used.

"The packing of blueberries has been carried on for twenty-five years, the blueberries in this State being principally obtained in the East now, more coming from Cherryfield than all the other parts of the State combined. Blueberries are not so readily obtained now for packing purposes as in former years, as they are worth more for the market than they are for canning. For canning, it is necessary to have the berries very fresh. It takes about three quarts of blueberries, as we receive them, to fill two one quart cans, as the berries shrink in bulk when cooked.

"The canning of beef and mutton is a branch of the packing industry which received its chief start at the breaking out of the rebellion, and since which time there has continued to be a good market for these goods. In packing, the usual method is to separate the bone from the meat, and to cut up the meat and put it into the cans, it being desired to put in an assortment from different parts of the animal. The medium quality of beef and mutton with respect to fatness is considered the best for canning, although it is more economical to pack good weight beef. An ox of medium size contains about eighty pounds of bone, and the more there is of the animal the more we have to can. So in buying live weight, we get more shrinkage in proportion in buying poor cattle than in buying fat cattle. I suppose an ox of average weight will fill 500 two pound cans. The bones, after being separated from the meat, are put into a boiler by themselves, the top of which is secured by bolts. They are then steamed until everything of value is taken out, and they will then break and crumble as easily as corn cobs. The bones are then sold to phosphate companies, and the stock which is obtained from them by steaming is used for soups, etc., a certain amount being used for glue stock. It is intended to utilize the entire animal in this way.

"I do not know that any salmon is packed in Maine. We go to the provinces for that class of fish, taking along our men, machinery, and tools. The fish are then purchased from the fishermen and taken to the factory, where the scales are removed and they are thoroughly cleaned. They are then cut into lengths suitable to go into the cans lengthwise. It is weighed before it goes in. In putting the fish into the cans a tunnel is used, which is of the size of the ends of the cans, and the salmon is compressed through the tunnel into the can, and if it is necessary to make the can of the proper weight, another small piece is added. A certain amount of liquid is put into the cans, salt, pepper, etc. The can is then sealed, and goes through the bathing process, much in the same manner as in packing meats.

"Upon the main coast, we pack a large quantity of mackerel and lobsters. The mackerel are obtained from mackerel fishermen, who go out and catch them and bring them in and sell them per the hundredweight to the packers. The mackerel are cleaned in the same manner as for cooking, and are then cut up in proper lengths and put into the cans. A certain amount of water and salt are added, and they go through the bathing process in the same manner as meats and salmon.

"In the lobster packing business, the lobsters are obtained from lobster fishermen, who make their living by catching that kind of fish. They use traps baited with fish, which they sink to the bottom of the sea, and into which the lobsters enter through a small opening constructed for that purpose. After they once enter, they are unable to retreat. A buoy upon the surface marks the location of the trap. The fisherman then draws the trap to the surface, removes the lobsters, and returns the trap to the bottom again. The lobsters are then taken to the factory, and if it is in the height of the season, when the factory is receiving more than it can pack, they are put into cages made for the purpose, and sunk in the water, where they are kept until they can be handled. At the proper time they are taken up and put into kettles of boiling water, alive. By boiling, the shell of the fish is changed from a dark green to a red color. They are generally boiled in the afternoon, and the next morning they are ready for packing. The claws are cracked so that the meat can be readily removed, and they are completely pulled to pieces and dissected. The meat is then carried into a room and placed upon a long table, where it is put into cans, the intention being that the girls who fill the cans shall put in each an assortment of the meat, so many ounces being put into each can. Open top cans are used, and after the meat is placed in them, the top is driven in, and they are sealed up and bathed in much the same manner as other fish. The next day the cans are taken and thoroughly cleaned and painted and labeled. The one pound cans are packed in boxes of four dozen each, and the two pound cans in boxes of two dozen each. Under the present law in Maine, fishermen are not allowed to take lobsters under a certain length. The market for lobsters extends into very many foreign countries, a very large proportion of them being sent to Europe.

"There are now twenty-eight corn factories run by the three leading concerns in Maine, and about a dozen by outside parties. Nearly all the lobster factories are situated by themselves. There are about eight lobster factories in Maine, but there are very many in the provinces operated by Maine companies. There are some Boston parties operating upon the Maine coast, among whom are Messrs. William Underwood & Co.

"The principal packing companies in Maine are the Winslow Packing Company, the Portland Packing Company, and Messrs. Burnham & Morrill. The Winslow Packing Company do the most extensive business, operating lobster factories at Boothbay, Vinalhaven, Camden, Bass Harbor, and Deer Isle, in Maine, and in the Provinces four factories in the vicinity of Shediac, N. B., one at Sober Island, one at Bay of Islands, N. S., and one at the Magdalen Islands, and corn factories at Bridgeton—which is the oldest and largest factory in the State, it having now been in operation twenty years—Raymond, Hiram, Buckfield, Canton, Mechanic Falls, Norway, Deering, Fairfield, Skowhegan, North Anson, Farmington, Wilton, and West Waterville. The total pack of these factories, when run to their full capacity, is about 20,000 cases of lobsters, or 48 cans to the case, and 200,000 cases of corn, 24 cans to the case. In 1883, which was a year of quite large production, the Winslow Packing Company sold over $500,000 worth of canned goods. The factory at Raymond will be operated the present season by the Portland Packing Company.

"The Portland Packing Company have factories at Fryeburg, Sebago Lake, Winthrop, Vassalboro, Hiram, and Kennebunk. Messrs. Burnham & Morrill operate factories at Denmark, Harrison, South Paris, Minot, Scarboro, and Norridgewock. The Portland Packing Company and Burnham & Morrill do not have a very large lobster business on the Maine coast, but they are extensively engaged in that business in the provinces, the former company having, within the last two years, made large additions to their Province business. The Winslow Packing Company, in addition to their general packing business, have one factory devoted exclusively to the manufacture of cans, from which they sell large quantities to outside parties.

"The depressed state of the canned corn market, resulting from the overproduction of the years 1883 and 1884, has caused a remarkable decrease in the number of factories throughout the State, and the quantity of corn to be packed the present season will probably be much less than in 1883, although the prospect for ready sales is very good. Prices, however, will not range so high as in previous years, owing to the fact that the cost of tin is less than it has been for a long time, and labor is somewhat cheaper, and the corn to be furnished by the farmers will run a little lower in price.

"One good feature of the canned goods business is the fact that more than two-thirds of the cost of the goods remains in the State of Maine, the only materials purchased out of the State being tin, solder and labels. The amount of money paid to the farmers by these corn factories is many times greater than the amounts paid to this class of men in any other industry, being, on an average, in the neighborhood of eight hundred thousand dollars per year. The aggregate amount of canned goods produced in Maine, including corn, lobsters, sardines, and berries, is on an average not less than $1,500,000.

"Should there be any important war in Europe, the demand for canned meats and other goods used by armies in the field would stimulate the packing industry to a great degree. In Chicago and San Francisco there are already established large can making establishments capable of producing upward of 25,000 cans per day, in which a sheet of tin is turned into a can without any skilled hand work, the whole thing being done by machinery, and a very handsome and substantial can being produced; but the expense of starting these large establishments is so great that none has been attempted upon the Atlantic coast yet.

"The oldest practical corn packer now living is Mr. Albion H. Burnham, one of the superintendents of the Winslow Packing Company, who began packing with Nathan Winslow, the brother of Isaac Winslow, the originator of the famous brand of 'Winslow Corn,' Mr. Burnham having been engaged constantly in this business since 1851. Prior to that time the packing industry in Maine had been confined to within very narrow limits, the only corn factory in existence in 1851 being a small building of about 40 by 20 feet, the whole annual output of which was less than a thousand cases, valued at that time at about $4,000.

"Much prejudice exists against canned goods on account of the alleged careless use of acids used in manufacturing cans and in sealing the same, and this very fact should deter people from purchasing any canned goods except such as are put up by reputable concerns under their own labels. It is believed that there is no injury to health on record resulting from the use of canned goods which where put up by any reputable concern. The difference in the prices of good canned goods and the poorer grades is nothing as compared with the necessity of using wholesome food. Scientific investigations made within the past two years have demonstrated that nearly all the cases of sickness, which are comparatively few considering the vast quantity of goods consumed, have resulted from the packing of damaged goods. Lieutenant Greely, of Arctic fame, has given a special certificate to the effect that out of the large lot of canned goods with which his explorers were supplied, only one can was found defective. During the past season, one lot of canned goods were sold by a New York concern to go to a

missionary post in Africa, which had to be transported by negroes on foot one thousand miles from the point of unlading.

"Considering the fact that canned goods are really the only article of food which will successfully withstand the rigors of an Arctic winter as well as the heat of the Tropics, and the additional fact that new countries are being constantly settled, it is apparent that the demand for this article of food will increase rather than decrease.

"The consumption of canned goods in the mountain regions and in the Western Territories and the new States is simply enormous. Many of the Western States are now producing canned corn of a very good quality, and can do this at much less expense than in Maine, but while the corn averages very good, yet it is believed that no State has succeeded or will succeed in producing canned corn which will be as nutritious, sweet, and tender as that produced in Maine. This facts results in a great measure from the nature of the soil and the large quantity of manure required and the rapid growth of the corn. A recent chemical analysis of corn packed in Maine, Maryland, and one of the Western States disclosed the following as to the food value of the three lots, namely: Winslow's corn, 456 8-10; Iowa corn, 350 7-10 and Maryland corn, 303 7-10. In other words, the Winslow stood 30 per cent. above the Iowa and 50 per cent. above the Maryland in food value; or, if Maryland corn is worth 80 cents per dozen, and the Iowa a dollar, the Winslow would be worth one dollar and twenty cents. Among the modern improvements for packing corn are the steam retorts, which do the process in about an hour and thirty minutes, whereas the Winslow process requires about five hours. While many of the packers have adopted the retort system, the Winslow Packing Company still retains the old five hour process, which is more expensive than the modern processes, but which this company claims gives a better quality of corn.

"In connection with this business, the printing of labels for cans has grown in like proportion, from plain labels of one color on white paper to labels of many colors, needing the most skillful designers, and the large capacity for production, requiring presses of the latest manufacture. The largest number of labels are printed in Boston, there being no label printing establishments in Maine."

ON THE EMPLOYMENT OF GAS FOR COOKING.

By W. Ivison Macadam, F.C.S., F.I.C., Edinburgh.

The subject of cooking by gas is one of the most important which is at present before the gas manufacturing industry. Great strides have of late years been made in this direction; and the many hundreds and thousands of "cookers" now in use in various cities and towns speak volumes in favor of the system. Ignorance, prejudice, and an attachment to time-honored usages all tend to retard the general introduction of gas as a substitute for coal. Soot, smoke, and ashes are so familiar to every cook, that the idea of providing meat without these being present seems both impossible and improbable. The fact that the ordinary open fire or cooking range only does very imperfectly what the gas retort manufactures in a pure state seems to be ignored, and the public continue to burn valuable deposits of fuel, at the same time wasting the greater part of the constituents it yields, and polluting our atmosphere with that large quantity of finely-divided carbon which, accompanied by water-vapor, goes to produce those dense fogs which envelop our cities from time to time, causing loss of business, and being at the same time a hotbed of disease. Much of the dust and a large proportion of the dirt which soils our linen and makes city life almost unbearable can be traced to smoke. Moreover, the carbon in this state is useless, and is simply wasted; for plants cannot assimilate it, while the sulphurous acid fumes, etc., which accompany the sooty particles kill all the more tender and beautiful plants which delight our eyes, and render it impossible to grow healthy, strong, and vigorous trees in populous places. Much of the beauty of Continental cities may readily be traced to the custom of the inhabitants of cooking with charcoal, from which no carbon in a free state is evolved.

The very great waste of fuel rendered possible by the use of the common coal fire can be readily understood when we remember that a ton of coal can, with ease, be consumed in a month; while if the same amount of the substance were placed in a retort and distilled, a quantity of gas would be obtained equal to about 8,000 cubic feet, and sufficient to keep an ordinary-sized family in cooked provisions for a period of fully six months. The actual money value of the fuel is also increased; for from the ton of coal, which may be estimated as being worth 16 s., we get 8,000 cubic feet of gas, which at 2 s. 6 d. per 1,000 cubic feet will be equal to a sum of 20 s., and the residue of coke left in the retort may be put at half a ton in weight and at 8 s. in money value. We thus have a return of 28 s. for the ton of coal, worth 16 s., and have as residual materials all the tar and ammoniacal liquor produced. Moreover, to the gas consumer a very great saving in money is effected; for while the 20 s. worth of gas will cook for him for six months, he would require, in using coal, to expend at least 96 s. in the same time.

Granting, then, that some advantage may be gained by the employment of gas, the question comes to be, How we are to adapt our arrangements so as to obtain from the fuel the greatest amount of the available heat? To thoroughly understand this part of the subject it will be necessary for us first to have a knowledge of the nature of combustion, and of the products derived therefrom. It is now generally known that ordinary coal gas contains, as its principal constituents, marsh gas, hydrogen, carbonic oxide, and ethylene, with an admixture of nitrogen and carbonic anhydride. The first three of these gases yield, when burned, flames which are practically non-luminous, but which give a considerable proportion of heat; while the ethylene burns with a luminous flame, and gives, in addition to the heat, a certain proportion of light. These gases have no power within themselves of supporting combustion; and, when introduced in a lighted state into an atmosphere of their own gas, are instantly extinguished. The process of combustion, in its commonly accepted sense, consists of the oxidation of the constituents of the gas; and the presence of more or less oxygen is essential. This oxygen is derived from the air, which contains about 21 per cent. of it by volume; the remaining 79 per cent. consisting of nitrogen. This latter gas is an inert body, and acts merely as a diluent. It is not combustible, and does not support combustion; nor does it enter into combination with any portion of the gas when the latter is burnt in air. The oxygen, on the other hand, readily combines with or oxidizes the carbon and hydrogen of the gas, whether these substances are present in the free or elementary state, or combined together. The oxygen, however, has a much greater desire to attach itself to the hydrogen than to the carbon; and the result is that, where substances rich in carbon are present in the coal gas, a certain amount of the carbon is thrown out of its states of combination, and floats in the flame. These small solid particles, becoming highly heated, begin to radiate a proportion of the heat, and at the same time to radiate also a considerable quantity of light. This throwing out of carbon from its state of combination is principally found to take place by the disintegration of the heavier hydrocarbons, of which ethylene may be considered the type.

This, then, is the explanation of luminous flame. The oxygen of the air, selecting the hydrogen in preference to the carbon, causes the latter body to be returned to the solid state; and these little particles of carbon, then becoming highly heated, emit light. This reaction is carried on in the luminous portion of the ordinary white gas light, and is marked as zone B in the annexed diagram.

This zone is known as the area of partial combustion, or selective combustion, because the reaction between the oxygen and the hydrogen only proceeds; the carbon being thrown out of its states of combination as a solid body. The zone A is the area of no combustion. The extent of this area depends greatly on the pressure at which the gas is forced through the pipes toward the burner. The greater the pressure, the larger the area. In the better class of burners various devices are employed to check the flow of gas; and the more perfectly this is accomplished the better the burner—the greater the zone B will become, and consequently the more light will be obtained. In zone A the air has not impinged on or become mixed with the gas; and therefore no active combustion can proceed. Outside of zone B another (and usually invisible) zone, C, is found. In this area the carbon which in B has been producing light meets with the oxygen of the surrounding air, and becomes oxidized or burnt into carbonic anhydride. This is the area of complete combustion. Place a small white plate over an ordinary gas-flame, and—provided the gas-burner is a good one, and the plate be held not nearer than (say) 3 inches to the visible flame—no soot or carbon will be deposited on the plate; in other words, perfect combustion is taking place. Now lower the plate until it touches the luminous portion, and immediately it becomes black from the deposited carbon, which was previously floating in the flame, and producing light. The result, then, of burning gas in an ordinary burner is the complete oxidation of the carbon and hydrogen of the gas into carbonic anhydride (carbonic acid) and water vapor. The luminosity of the flame depends upon the fact that a sufficient quantity of air is not present to burn both the hydrogen and carbon, and that the oxygen, having a preference for hydrogen, selects this element, and leaves uncombined carbon floating in the flame. Provided, therefore, that we can, by some means, mix with the gas, before it arrives at the burner, air in quantity sufficient to oxidize both the hydrogen and the carbon, the result should be a non-luminous flame, or a combustion in which we have no area B, but only zone C. Such is the principle of the Bunsen, or blue or atmospheric, burner. In this burner, air is admitted, and mixed with the gas, and the resulting combination burnt; the flame being perfectly non-luminous when properly worked. Having no solid in the flame, we can have no radiation of heat; and consequently, the whole calorific power of the burner is concentrated immediately over the flame.

Such are the flames available for utilizing the gas fuel for cooking purposes—the one a radiating flame, the other a concentrated heat flame. Suppose now that we desire to roast or bake in a oven; the heat we wish will be a radiant one. We do not intend to bathe the meat or bread in the heated vapors evolved from our burning gas, but we wish to conserve their heat, and radiate it from the heated sides of the oven, and also from the flame itself, if possible. If, then, we use ordinary white-flame jets, we shall obtain the desired effect. The blue flame will also enable us to cook in the oven; but the radiation will be entirely from the sides of the metal plates, and none from the burner itself. The white flame is, therefore, to be preferred. Moreover, if we desire a low heat, and our apparatus is fitted with blue jets, we are liable to set up an imperfect combustion, which produces a variety of hydrocarbon in which only one-half of the hydrogen has been oxidized, viz., acetylene. This body is one with an acid smell and somewhat irritating properties; and it readily taints meat placed in its vapor. With the white light this substance cannot be produced, unless, indeed, the burner fits badly, and is allowed to burn at the sides. This partial combustion, or "striking back," is the great difficulty of the blue flame when applied to close ovens. Another difficulty arises in the more or less liability of the jets to be blown out when the door is rapidly closed; care being especially necessary with the blue flame. For boiling vegetables or water, or for grilling or toasting, the oven heat is not available; and therefore other apparatus is necessary. The burners for these purposes are placed over the oven, and are not closed in. For boiling it is desirable to have a flame which concentrates the heat at one point; and therefore, the blue or atmospheric burner is to be preferred to the white or heat-radiating burner.

For roasting purposes the temperature required is one about 340° Fahr., while for baking a somewhat higher heat is desirable. There is no difficulty in raising the heat in the gas cooker to as high as 400° to 500°, or even higher; and one of the points to be guarded against is the possibility of having too high a heat. Not only does a high temperature mean waste of gas, but it also causes loss in the weight of the meat by undue evaporation of water vapor; and at the same time the fat is liable to be decomposed, the glycerine being converted into a body called acroylein, which possesses an extremely pungent odor and poisonous properties. Care, therefore, is necessary to avoid too great a heat in the oven. This difficulty might be guarded against by making the stove-gas pipe of smaller dimensions; but the rapid heating of the oven to the roasting temperature would then become impossible. The best method is to turn on the gas fully for about a quarter of an hour, when the proper heat will have been attained, and then to lower the gas one half. For this preliminary raising of the heat, about 3 cubic feet of gas will require to be burnt, which is equal to an hourly consumption of 12 cubic feet; but the proportion necessary for the after-cooking of the joint will not exceed 6 cubic feet, or say a total consumption of 20 cubic feet in the two hours required for the thorough cooking of the joint.

One point in the cooking of meat by gaseous fuel is the very small loss sustained in the actual weight of the meat operated upon. In an ordinary coal range, the loss in weight through cooking amounts to fully 40 per cent. In other words, every 100 lb. of meat treated represents 60 lb. of cooked material, or a 10 lb. joint only weighs 6 lb. after roasting. This is the result with our common coal-fires. With gas, however, we find that the actual loss in weight is reduced from 40 per cent. to 25 per cent., or 100 lb. of raw meat becomes 75 lb. of cooked material, and a 10 lb. joint comes out of the gas cooker weighing 7½ lb. That this should be so is readily understood, when we remember that one of the constituents of the combustion of the gas is water vapor—1 cubic foot of gas producing about 1½ cubic feet of steam vapor—and that, therefore, there is not the same tendency for water to escape from the joint. The meat, too, when cooked by gas, is less shrunken and more juicy, and is, therefore, more easily digested than food cooked by the ordinary methods. It also cuts up better, and goes further. Being more juicy, it has not the same keeping powers as the drier coal-cooked meat has; and, therefore, it should be retained for a shorter period before consumption.

From the foregoing figures it is easy to calculate the amount of gas which will be consumed in cooking a dinner for eight or ten persons. An ordinary joint of some 10 to 12 lb. weight requires from 1½ to 2 hours for cooking; and after making all allowances for extra time in raising the heat of the oven and some waste, the total quantity of gas should not exceed 20 cubic feet for the 2 hours, or 10 cubic feet per hour. The oven, moreover, will not only cook a joint, but pastry can be baked at the same time, and that without extra cost for fuel. Vegetables can be boiled or steamed on the upper open rings, or "boilers;" and as the ranges are usually furnished with at least three of these appliances, so many pots can be kept at work. These upper rings will consume a quantity of gas equal to that required by the oven, and therefore we must double our previous estimate of gas, and lay our account for a total consumption of 40 cubic feet for the two hours' cooking of a dinner for eight or ten persons. But let us employ a figure certain to cover even careless working, and say 50 cubic feet, or 25 cubic feet per hour, what is the actual money cost of cooking this dinner? Supposing the gas costs 2 s. 6 d. per 1,000, or 3 d. per 100 cubic feet, the 50 feet cost the consumer exactly 1½ d. Breakfast, tea, and possibly supper require to be provided, and also hot water for washing purposes. Let us, then, add 50 feet for these, and the total daily cost of cooking by gas for a family of eight or ten people may be set down at 3 d. For a like amount of work, an ordinary range would consume at least ¼ cwt. of coal. This at 16 s. per ton is equal in money value to about 5 d.; or a clear saving of 2 d. per day. Calculating these figures to the yearly cost, we find, from the above data, that the gas cooker costs the house £4 11 s. 3 d., and the coal range £7 16 s. 3 d.; showing a difference in favor of the gas of £3 5 s. per annum. In most families daily joints are not common, and cold meat must be consumed, with a consequent lowering of the gas bill. This in the case of gas will be equal to at least one-third, leaving the yearly cost of the gas cooker at £3 Of course a smaller amount of coal will also be required; but the fire must be kept burning, and therefore not a fourth less coal will be used. Allowing, however, this proportion, a deduction from the £7 16 s. 3 d. of £1 19 s. must be made, which leaves as the cost of the coal fire £5 17 s. 3 d., and gives a balance in favor of gas cooking of £2 17 s. 3 d. per year. That the above results are based on figures which may be relied on as above the possible cost will be acknowledged when it is stated that, in one case which has recently come to the writer's knowledge, where a gas cooker had been employed for some 14 months, and had during this period cooked the whole food for a family of six or seven people (besides visitors), the total gas consumed was 15,000 feet, at a cost of £1 17 s. 6 d., or abour 1 d. per day. For the same cooking by coal not less than 4 d. per day would have been required; and a saving was thus effected of £5 12 s. 6 d. for the period of 14 months. The actual coal bills of the family had been reduced to an even greater extent; but, accepting the above figures, the balance is on the side of the gas.

Further considerations may also be urged in favor of gas over coal for cooking. Not the least of these is the absolute cleanliness of the fuel. No dust is thrown into the air of the room, to be washed or dusted off; no ashes are left to be removed. Time is thus actually saved, and the labor conserved for other purposes. This last item is one of no inconsiderable importance; for, in a large establishment, service is required to carry coal and remove ashes first from the rooms, and then to the street or ashpit. Taking the sum of £7 16 s. 3 d., which we found to be the money value of the coal necessary for an ordinary family's cooking, and dividing it by the cost per ton—viz., 16 s.—we get 9¾ as the figure which

represents the number of tons of coal obtainable for the money. Now, these 9⅝ tons of coal require to be carried to the kitchen; and a small computation of the time necessary for this work will be some five minutes' daily labor, or a yearly period of 31¼ hours, or some three working days' labor. The ash left will amount to an average of (say) 5 per cent. of the coal—in other words, about ⅛ ton per annum; and allowing for the time occupied in cleaning, and in removing the refuse, not less than ten minutes per day will be required, or other six working days per year. The total saving of labor alone by the use of gas for cooking will thus be equal to nine day's work per year. Further, in lighting up the ordinary coal fire in the morning, paper and sticks are necessary, as well as labor. The sticks alone will be equal to 2 d. per week, and the labor to at least five minutes per day. The saving in sticks will amount to 8 s. 6 d. per year—a sum sufficient to keep the gas cooker working for a month; while the labor saved is again equal to three working days. Let us tabulate these statements:

	Gas Cooker.	Coal Range.
Cost of fuel	£4 11 3	£7 16 3
Cost of sticks	none	0 8 6
Total	£4 11 3	£8 4 9

Time employed—

In carrying coals (say)	3	working days.
In removing ashes and cleaning ash receptacle	6	" "
In lighting fires	3	" "
Saving in time by employing gas	12	working days per year.

The figures speak for themselves, and show that we may confidently expect, by the use of gas, to save in cooking operations some £4 per annum, and labor equivalent to twelve days per year.

Let us come now to the first cost of the stoves and ranges. An ordinary good kitchen range will cost about £12; and the building in and fitting up will amount to (say) £1 more. A better class of apparatus may be valued at from £20 to £30. Gas cookers of a size sufficient to do work similar to these ranges may be had for £6 15 s., and do not require building in. The gas companies will generally carry their own gas connections to the stove and supply meters. There are, therefore, no extras; and the saving on this head alone will be equal to nearly £7—a not inconsiderable economy in the furnishing of a house. Nearly all the gas companies now have gas cookers for hire, and these they supply to their customers at rents varying from 10 s. to 20 s. per year; the companies at the same time keeping the stoves in repair.

The question is frequently asked: "Is it not the case that gas-cooked meat tastes of the gas?" This is impossible, provided that even ordinary care is taken to insure complete combustion of the fuel. Let us inquire what burns, and what products are obtained therefrom. In my previous article I stated that ordinary coal gas consists of the following bodies: Hydrogen, carbonic oxide, ethylene and other hydrocarbons, marsh gas, and nitrogen. The proportions are given below:

Composition of Coal Gas.

	From Cannel Coal. (Bunsen and Roscoe.)	(Frankland.)	From Ordinary Coal. (Frankland.)
Hydrogen	45·58	35·94	50·05
Marsh gas	34·90	41·99	32·87
Carbonic oxide	6·64	10·07	12·89
Olefiant gas, etc.	6·46	10·81	3·87
Nitrogen	2·46	—	—
Carbonic anhydride	3·67	1·19	0·32

Of these substances only the nitrogen and the carbonic anhydride are not combustible. The gas, on burning, combines with the oxygen of the air, and the process of combustion is simply one of oxidation, or the combining of oxygen with the various elementary bodies present in the gases. The hydrogen burns into water vapor. The marsh gas consists of carbon and hydrogen (CH_4), and, on burning, yields carbonic anhydride and water vapor. The olefiant gas also contains carbon and hydrogen (C_2H_4), and gives off carbonic anhydride and water vapor. The carbonic oxide gives only carbonic anhydride. The nitrogen is an inert body. Carbonic anhydride is not absorbed by the meat in the hot condition, and the water vapor is harmless. Let us now look for a moment to what coal contains:

Chemical Composition of Coal.

	Per cent.	Per cent.
Carbon	79·68	81·19
Hydrogen	5·96	6·34
Oxygen	7·63	6·48
Nitrogen	1·21	1·34
Sulphur	0·33	0·27
Ash	1·57	1·21
Moisture	3·62	3·17

Coal, therefore, contains the very same bodies as gas; in fact, gas is simply the purified essence of coal, and is really a purer fuel, as it contains practically no sulphur. In burning, the coal has its carbon oxidized into carbonic anhydride, and the hydrogen passes into water vapor. The products, therefore, of the coal fire and the gas flame are the very same, viz., carbonic anhydride and water vapor. If gas is supposed to taint food in the cooking, why does coal not do so? The fact is that, so long as either coal or gas is properly consumed, neither substance can damage or render unwholesome the food placed over it. Burn the coal improperly, or employ too great a heat, and the result will be the production of noxious ingredients; and a similar result will be obtained with gas.

But while the products of the combustion of the gas cannot exert any influence on the quality of the meat, the waste products should not be allowed to escape into the atmosphere of the room. In working with an ordinary coal fire, the soot compels us to conduct our cooking under a chimney; and thus it frequently happens that people fancy it is only the deposited carbon which is objectionable. Were this the case, the substitution of anthracite or coke (neither of which gives a smoky flame) would enable us to do away with the vent; but it is well known that even in such cases a chimney is necessary. This necessity arises from the fact that carbonic anhydride (or, as it is commonly called, carbonic acid) is a very poisonous body. Frequently accidents have taken place, due entirely to want of care in the removal of the carbonic anhydride formed by combustion. It will thus be readily understood why it is necessary, and why in all cases it should be insisted upon, that a perfect system of ventilation be carried out in all rooms; and when coal or gas is burnt in the room, the necessity is even more urgent, for a greater quantity of the noxious ingredient is thrown into the atmosphere. By no known practical means can the products of combustion from a gas or coal stove be removed and rendered so innocuous as to be thrown into the air of a closed space without danger to the inhabitants. Sometimes it is urged that no greater danger can accrue from the products of the combustion of a gas stove than from the same ingredients produced at our common gas-burners. Now, in the first place, a common burner will rarely consume more than 3 cubic feet of gas per hour, or (say) 10 cubic feet per hour for three jets, while, in our gas cooker, we are burning from 40 to 50 cubic feet of gas per hour; so we are passing into the air as much carbonic acid every hour as we should form in a 3 jet luster in five or six hours, and as much as if we had from 40 to 50 adult persons in the room. In the second place, "two blacks do not make one white;" and while we may err in burning our lighting gas as we do, this is no reason why we are to continue in fault with our cooking appliances. In a word, then, every cooker should communicate with the outside air, either directly, by passing the flue through the wall, or into a chimney. In most gas cooking-ranges, flues can only be attached to the ovens, and thus only half of the spent gases are carried off. By the very simple arrangement of adjusting a hood over the upper boiling-rings, the fumes of the burnt gas and the odor of cooking can be removed into the chimney. This is a point to which stove makers have not given sufficient attention. One very easy method is to stand the gas cooker in the fireplace, leaving the chimney perfectly open. In most cases where this arrangement is carried out, no flues whatever need to be attached to the range; but should the chimney not draw well, then a few feet of stove-pipe (say 6 feet) can be fixed to the cooker, and passed up the chimney. No iron plate is necessary over the stove, and none should be allowed, as such only stops ventilation by the chimney.

The quantity of the gas supplied in our towns and cities varies greatly; and the question is naturally asked whether all these gases have a similar heat-producing power—whether the 25 to 30 candle power gas from cannel coal is as good as the 15 to 20 candle power gas obtained from a mixture of soft and cannel coal; and, if as good, what amount of heat can one obtain for a certain sum of money or from a given quantity of gas. The substances to be considered in answering these questions are the combustible bodies only; in other words, the hydrogen, marsh gas, olefiant gas, and carbonic oxide. The proportion of heat produced during the combustion of these substances varies much. In calorific power, hydrogen stands first. This is followed by the marsh gas and olefiant gas; the carbonic oxide giving only a very small proportion of actual heat. The following table gives the units of heat obtainable by the combustion of 1 gramme (15·43255 grains) weight of each of the gases named:

Heat of Combustion.

1 gramme of hydrogen	=	33,808	thermal units.
" marsh gas	=	13,108	"
" carbonic oxide	=	2,431	"
" olefiant gas	=	11,942	"

In other words, we find that hydrogen gives during combustion 2½ times more heat than marsh gas, nearly 3 times (2·83) that of olefiant gas, and almost 14 times that obtainable from carbonic oxide. Marsh gas is rather more useful than olefiant gas, and 5¼ times better than carbonic oxide; and olefiant gas is better for heating purposes than the carbonic oxide in the proportion of 1 to 5. Where 1 part of hydrogen might be employed, the same heat could be obtained from 2½ parts of marsh gas, 3 parts of olefiant gas, or 14 parts of carbonic oxide.

The composition of gases obtained from cannel and ordinary coal has been already noted. The figures given in that table are percentages by volume; and before we can calculate the amount of heat obtainable we must convert them into percentages by weight. The following table is so calculated:

Gas from Cannel Coal.

	Percentage Composition by Volume.		Weight of Substance in Grammes.		Thermal Units obtained on Complete Combustion of 100 parts of Gas by Volume.
Hydrogen	45·58	=	4·073	=	137,699·984
Marsh gas	34·90	=	24·944	=	326,965·952
Carbonic oxide	6·64	=	8·302	=	20,182·162
Olefiant gas	6·46	=	8·078	=	96,467·476
Nitrogen	2·46				
Carbonic anhydride	3·67				
Total thermal value of 100 volumes of gas					581,315·574

Gas from Ordinary Coal.

	Percentage Composition by Volume.		Weight of Substance in Grammes.		Thermal Units obtained on Complete Combustion of 100 parts of Gas by Volume.
Hydrogen	50·05	=	4·472	=	151,189·376
Marsh gas	32·87	=	23·496	=	307,985·568
Carbonic oxide	12·89	=	16·114	=	39,173·134
Olefiant gas	3·87	=	4·844	=	57,847·048
Nitrogen					
Carbonic anhydride	0·32				
Total thermal value of 100 volumes of gas					556,095·126

It would thus appear that no great difference exists, so far as calorific power is concerned, between a gas of low and one of high lighting power. This is no new point; for it has frequently been suggested that gas companies should manufacture two gases—one from cannel coal for lighting and the other from common coal for heating and motive power. Such, however, must entail enormous expense; as, in most cases, it would be equivalent to the building of entirely new gas-works, and in all cases the laying of miles of pipes. Moreover, all houses in which gas for heating purposes was employed would require to be furnished with two sets of pipes; and, therefore, it becomes most doubtful whether any saving would be effected. It comes to be a question whether gas companies should not allow a considerable percentage off the cost of gas used for cooking purposes. In the statistical report on the Gas Supply of Scotland, published by the Committee of the North British Association of Gas Managers, it is stated that in Easter Buckie—a small village of 2,500 inhabitants, where the total annual make of gas is only 1,600,000 cubic feet—the cost of gas for heaters and cookers is 3 s. 9 d. per 1,000, while for ordinary lighting purposes the charge is 7 s. 6 d. per 1,000 cubic feet. So far as stated in this report, Easter Buckie stands alone in respect to heating and cooking; but the point is one well worthy the attention of gas companies.

From the figures previously given, it will be easy to estimate the cost at which gas ceases to be cheaper than coal for cooking purposes. Taking coal at 16 s. per ton, and gas at 2 s. 6 d. per 1,000 cubic feet, a balance was found in favor of gas equal to fully 50 per cent.; in other words, gas cost only one-half what coal would have done. It therefore stands to reason that, in all places where the price of coal does not exceed 16 s. per ton, the gas supply should not cost 5 s. per 1,000 cubic feet to effect a saving by its use. Even at this price the only points in favor of the consumer will be the cleanliness and ease of working—points which are, however, by no means to be disregarded.—*Journal of Gas Lighting.*

LACTIC ACID IN THE STOMACH.

BEFORE the Physiological Society, Berlin, Prof. Ewald recently spoke on the occurrence of lactic acid in human gastric juices, which was now universally regarded as a pathological formation, *i. e.*, a product of fermenting processes which did not obtain under normal conditions. In conformity with this opinion he had, in a former investigation, clearly demonstrated the absence of lactic acid, even after milk had been partaken. On the other hand, he had regularly found hydrochloric acid in the gastric juice. Two cases of hysteric vomiting, which had come under his observation in the infirmary, induced him to resume this investigation, one of the cases especially inviting such inquiry. The female patient was able to retain on her stomach and normally digest solid food, but whenever she swallowed anything fluid the whole contents of the stomach were at once vomited. Opportunity was, therefore, here offered at any time to examine the contents of the stomach after food had been received. Prof. Ewald mentioned the different chemical reactions by means of which the presence of lactic acid might be easily detected in the gastric juice, and among them he deemed carbolic acid and chloride of iron the most trustworthy. He then described the experiments he had carried out on the female patient above referred to, which had yielded the following results: After a mixed meal (of bread, vegetables, and meat), lactic acid was found 26 times out of 31 in the contents of the stomach in the space of 10 to 100 minutes after the reception of the food; in 5 cases, however, not till 120 minutes or more after that point of time. Hydrochloric acid was found in the contents of the stomach only in the second hour and later, after the lactic acid had disappeared. Out of 26 cases in which white bread was alone eaten, lactic acid was demonstrated in 17 cases, occurring in 10 to 100 minutes from the time of eating. Out of 15 cases in which cooked albumen was administered, lactic acid was found only in one case, within one and a half hours from the time of its being taken; while, on "schabefleisch" (scraped raw meat) being administered, lactic acid became again demonstrable; in the majority of cases in 10 to 100 minutes' time. From these experiments it was to be inferred that lactic acid occurred normally in the contents of the stomach, namely, in the first period of digestion. It was, however, in the opinion of Prof. Ewald, no normal constituent of the gastric juice, but in the case of a mixed and meat diet originated in the carno-lactic acid obtained from the meat, and, in the case of white bread being taken, from the fermentation of the starch. On albumen being taken, lactic acid was, therefore, not found, because it occurred in the stomach only when it was introduced with the food—in the case of meat, for example—or when it arose from a fermentive aliment. With reference to the ulterior issues of the lactic acid, the speaker adopted the view of Prof. Maly, that it was employed toward the formation of the free hydrochloric acid afterward appearing in the gastric juice.

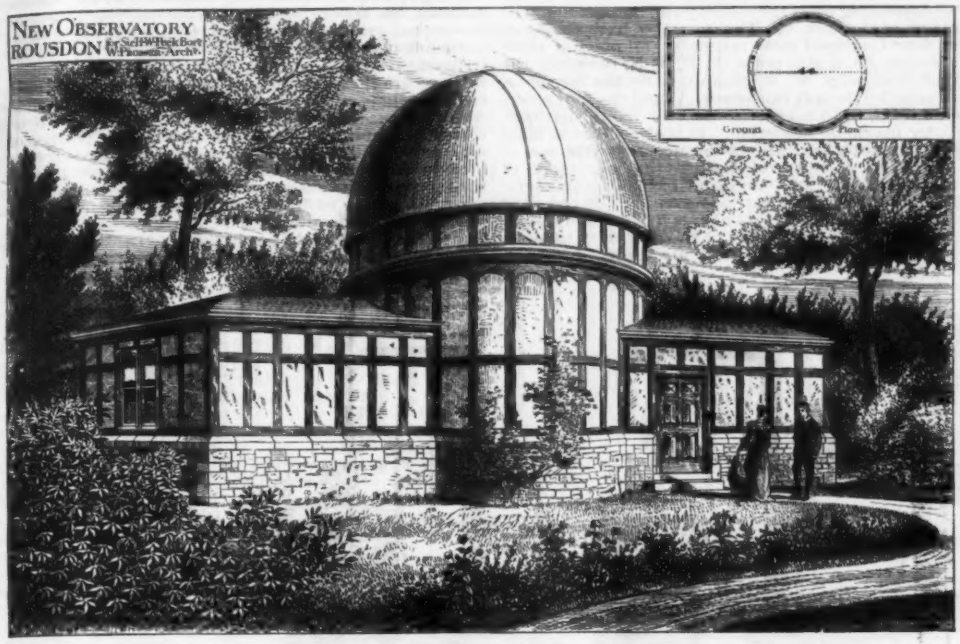
ON A VARIATION IN THE SIZE OF AN IMAGE ON THE RETINA ACCORDING TO THE DISTANCE OF THE BACKGROUND ON WHICH IT IS SEEN.

By ALFRED BROTHERS, F.R.A.S.

THE effect on the retina when the eyes have been fixed intently for a few seconds on a brightly illuminated colored object is well known; the color complementary to the one looked at always appears when the gaze is removed to a colorless surface. It is also a matter of common observation that when the eyes have been directed to a bright light for a short time, the image left on the retina as seen when the eyes are averted is *dark;* but if the eyes are rapidly opened and closed, the image is still seen *bright.* I am not aware, however, that it has ever been noticed that this image varies in size according to the distance of the background to which the eyes are directed. A circle of gas jets, perhaps, affords the simplest test. It will be seen, after looking at the circle of light for a few seconds (in some cases a more or less lengthened gaze at the light is necessary, owing to the varying sensitiveness of the retina), that if the vision be turned to a distant background the size of the image is instantly enlarged, and then, if the eyes be directed to a near background, the image is reduced in size. If any difficulty should be found in seeing the reversed image of the gas jets, it may readily be seen as a bright object by rapidly closing and opening the eyelids. The effect is the same as if the image were seen through a cone, the apex of the cone being held close to the eyes. In other words, the effect is the reverse of the ordinary rules of perspective.

ROUSDON OBSERVATORY, DEVON.

THIS is erected by Mr. Cuthbert E. Peek, M.A., F.R.Met.Soc., F.R.A.S., in the pleasure grounds at Rousdon, the seat of Sir Henry W. Peek, Bart., and is constructed of teak timber framing, filled in with cement concrete between the timbers, and resting on an elevated base of Doulting stone and flint facing. It has a waiting room and transit room, with photographic room between, and over the latter, under the dome, is the observing room. The dome is a revolving one, 16 ft. diameter, and covered with copper. The roofs of the waiting and transit rooms at the sides are covered with lead, and the joists are wrought and exposed to view inside. The interior is battened, and lathed and plastered, to insure perfect dryness of the walls in such an exposed position. The observatory is a short distance from the sea cliff, at an elevation of 534 ft. above mean sea level, and has an uninterrupted horizon to the southward, over the beautiful bay between Start Point and Portland Bill. Its latitude is 50° 42' 12" north, longitude 3° 0' 15" west. The observing room under the dome is fitted with an achromatic telescope by Merz, of Munich; it has an object glass of $6\frac{4}{10}$ in. aperture, and a length of about 8 ft. This is mounted on a massive equatorial cast iron stand by Cooke, of York, the iron pillar being 7 ft. above the level of the floor, and resting on a solid brick pier built in cement. Motion is given to the telescope by a clock movement controlled by a pair of governors, and provided with adjustments by which the rate can be made to coincide with the solar, lunar, or sidereal movements. The transit instrument in transit room is by Troughton & Sims, and has a telescope of 2 in. aperture and 24 in. focus. The optical power is sufficient to allow the transits of first magnitude stars to be taken within one hour of noon, and the time is kept by two chronometers by Dent. Mr. William Prosser is the architect of the work.—*Building News.*



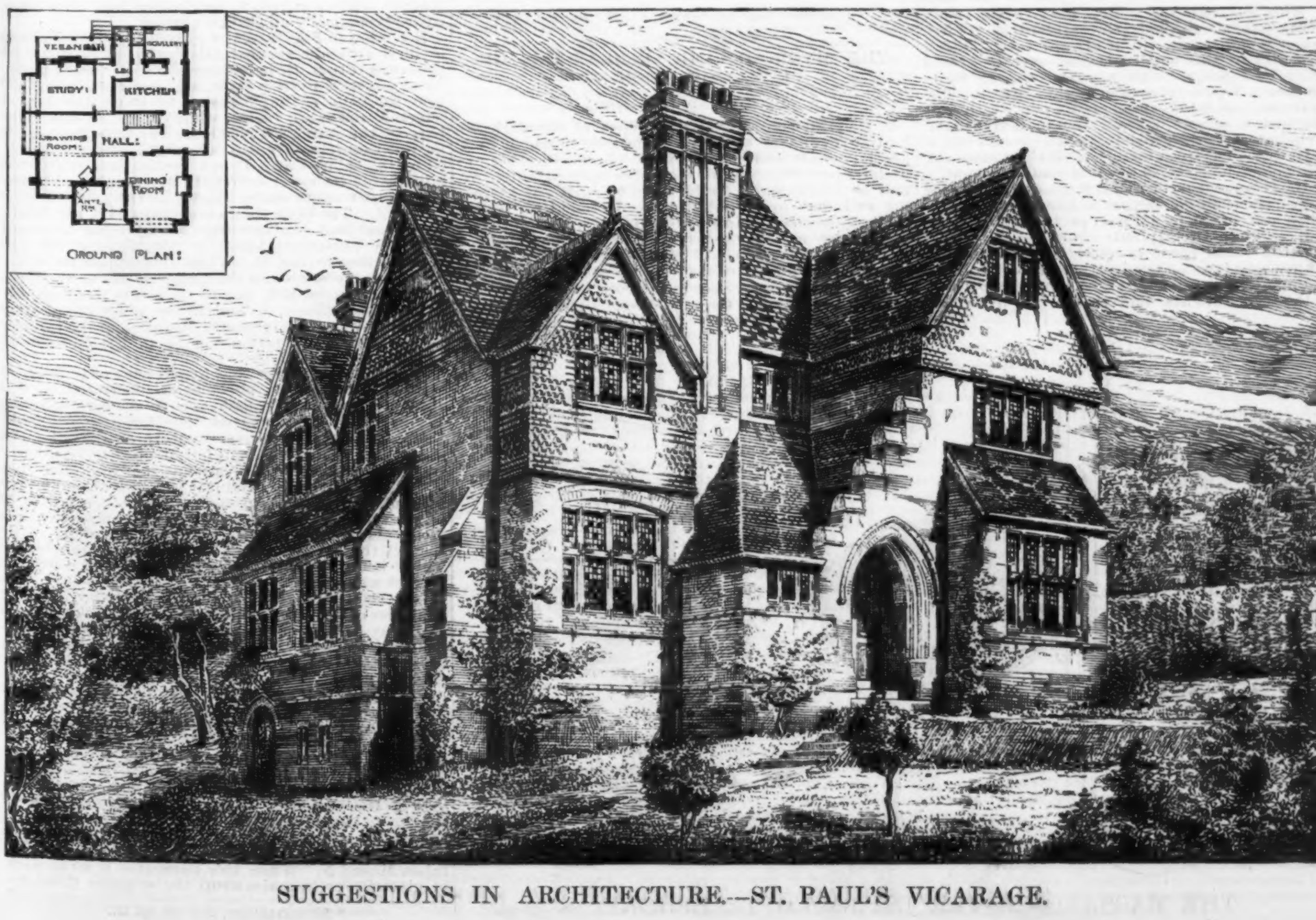
ROUSDON, A NEW PRIVATE OBSERVATORY.

ST. PAUL'S VICARAGE, FOREST HILL.

THIS building is erected at Forest Hill, Kent, and is from the design of Mr. E. W. Mountford. The drawing from which our illustration is reproduced is hung this year at the Royal Academy.—*Building News.*

MIND AND MOTION.

THE Rede Lecture lately delivered in the Senate House at Cambridge, by Mr. G. J. Romanes, M.A., F.R.S., was entitled "Mind and Motion." After giving some account of the teaching of Hobbes, who laid it down, on the one hand, that all our knowledge of the external world is but a knowledge of motion, and, on the other, that all our acquisitions of knowledge and other acts of mind imply some kind of "motion, agitation, or alteration, which worketh in the brain," Mr. Romanes pointed out, as regards the internal world, that physiology has proved that molecular movements of nervous matter are concerned in all the processes of reflex action, sensation, perception, instinct, emotion, thought, and volition. The lecturer detailed the discoveries which of late years have been made by physiology concerning the rate at which these movements travel along nerves, the period of molecular vibrations in nerve centers, the time required for processes of thought, and the quantitative relations between brain-action and mind-action. When physiological instruments fail to take cognizance of these relations, we gain much additional insight touching the movements of nervous matter by attending to the thoughts and feelings of our own minds, for these are so many indices of what is going on in our brains. Proceeding to contemplate the mind, considered thus as a physiological instrument of the greatest delicacy, he argued that the association of ideas is but an obverse expression of the fact that when once a wave of molecular disturbance passes through any line of nerve structure, it leaves behind it a change in the structure, such that it is afterward more easy for a similar wave when started from the same point to pursue the same course. Such being the intimate relation between brain-action and mind-action, it has become the scientifically orthodox teaching that the two stand to one another in the relation of cause to effect. He pointed out that the doctrine of conscious automatism is logically the only possible outcome of the theory that nervous changes are the cause of bodily changes, and, therefore, it cannot be fought on grounds of physiology. If we persist in regarding the relation between brain and thought exclusively from a physiological point of view, we must of necessity be materialists. But it does not follow from this that the theory of materialism is true; and other considerations of an extra-physiological kind conclusively proved that the theory is false. We have, first, the general fact that all our knowledge of motion, and so of matter, is merely a knowledge of the modifications of mind. Therefore, so far as we are concerned, mind is necessarily prior to everything else. Thus the theory of materialism assumes that one thing is produced by another thing, in spite of an obvious demonstration that the alleged effect is necessarily prior to its cause. But further, "motion produceth nothing but motion," says Hobbes, and yet he immediately proceeds to assume that in the case of the brain it produces, not only motion, but mind. Materialism has to meet the unanswerable question—How is it that in the machinery of the brain, motion produces this something which is not motion? Science has now definitely proved the correlation of all the forces, and this means that if any kind of motion could produce anything else that is not motion, it would be producing what science would be bound to regard as in the strictest sense of the word a miracle; causation from brain to mind is in the strictest sense of the word a physical impossibility. *Mutatis mutandis*, the theory of spiritualism—which supposes causation to proceed from mind to body—is, he held, but little less unphilosophical than the opposite theory of materialism. For just as it follows from the conservation of energy that motion can produce nothing but motion, so it equally follows that motion can be produced by nothing but motion. Is there, then, any third hypothesis in which we may hope to find intellectual rest? If we unite the elements both of spiritualism and of materialism, we obtain a product which satisfies every fact of feeling on the one hand, and of observation on the other. We have only to suppose that the antithesis between mind and motion, subject and object, is itself phenomenal or apparent, not absolute or real; that the seeming quality is relative to our modes of appre-



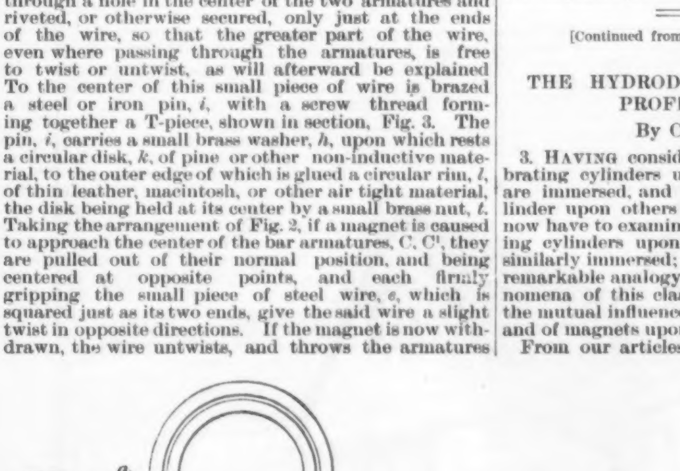
SUGGESTIONS IN ARCHITECTURE.—ST. PAUL'S VICARAGE.

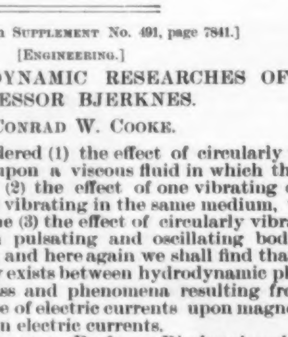
hension; and, therefore, that any change taking place in the mind and any corresponding change taking place in the brain are not really two changes, but one change. There is thus supposed to be only one stream of causation in which both motion and mind are simultaneously concerned; motion is supposed to be producing nothing but motion, mind-changes nothing but mind-changes. Both producing both simultaneously, neither could be what it is without the other, because without the other neither could be the cause which in fact it is. The use of mind to animals is thus explained, for intelligent volition is shown to be a true cause of bodily movement, seeing that the cerebration which it involves would not otherwise be possible. This monistic theory thus serves to terminate the otherwise interminable controversy on the freedom of the will; for the theory shows it to be merely a matter of terminology whether we speak of the mind or of the brain as the cause of bodily movement. That particular kind of physical activity which takes place in the brain could not take place without the occurrence of volition, and *vice versa*. All the requirements alike of the determinist and of the free-will hypotheses are thus satisfied by a synthesis which comprises them both in one. Mr. Romanes afterward reviewed the opinions of the late Professor Clifford upon this subject, and concluded by observing that if it were true that the voice of science must of necessity speak the language of agnosticism, at least let them see to it that the language was pure; let them not tolerate any barbarisms introduced from this side of aggressive dogma. So would they find that this new grammar of thought did not admit of any constructions radically opposed to more venerable ways of thinking, and that the often-quoted words of its earliest formulator applied with special force to its latest dialects—that if a little knowledge of physiology and a little knowledge of psychology incline men to atheism, a deeper knowledge of both, and still more a deeper thought upon their relations to one another, could only lead men back to some form of religion, which, if it be more vague, will also be more worthy than that of earlier days.

THE "BASSANO-SLATER" IMPROVED TELEPHONE.

THE accompanying sketches show an improved form of telephone receiver by Messrs. G. H. Bassano, A. E. Slater, and F. T. Hollins, of Derby, England. The inventors have been so good as to place at our disposal a receiver constructed according to their patent, and we find that it gives excellent results, being both sufficiently loud and very distinct in its articulation; it is, in fact, a good practical instrument. The very many patents taken out for telephone receivers are, as a rule, conspicuous only for their want of novelty. So far as we are able to judge, this receiver has several points in which it differs from others, and is generally a novel and, we understand, most effective arrangement, but it being *sub judice* we express no opinion as to its bearing on existing patents. Fig. 1 is a section of the complete receiver; Fig. 2 a plan of an improved arrangement or bar armature; and Fig. 3 a section of a steel wire T-piece, carrying a disk of pine or other non-inductive material. Corresponding parts are indicated by the same letters. Now in Fig. 2, *a* is a brass rim having an outer ridge or collar, *x*, and four small ears or lugs, *b*, *b*, *b*, *b*. C, C', are two soft iron bar armatures fixed on center screws, *d*, *d*, *d*, *d*. These two bar armatures are kept in a state of tension by means of a small piece of thin steel wire, *e*, passing through a hole in the center of the two armatures and riveted, or otherwise secured, only just at the ends of the wire, so that the greater part of the wire, even where passing through the armatures, is free to twist or untwist, as will afterward be explained. To the center of this small piece of wire is brazed a steel or iron pin, *i*, with a screw thread forming together a T-piece, shown in section, Fig. 3. The pin, *i*, carries a small brass washer, *h*, upon which rests a circular disk, *k*, of pine or other non-inductive material, to the outer edge of which is glued a circular rim, *l*, of thin leather, macintosh, or other air tight material, the disk being held at its center by a small brass nut, *t*. Taking the arrangement of Fig. 2, if a magnet is caused to approach the center of the bar armatures, C, C', they are pulled out of their normal position, and being centered at opposite points, and each firmly gripping the small piece of steel wire, *e*, which is squared just as its two ends, give the said wire a slight twist in opposite directions. If the magnet is now withdrawn, the wire untwists, and throws the armatures sharply back into their normal position. Now as the wire, *e*, carries the pin, *i*, and the disk of pine by its center, *k*, it follows that the latter, every time the armatures move, will also make a bodily movement backward or forward according as the bar armatures are attracted or released by the magnet. When, therefore, it is inclosed in a recess or air chamber, as in Fig. 1, a condensation and rarefaction of the air takes place in the recess formed by the cap, E, corresponding to the condensations and rarefactions of the air operating the electric current at the transmitter, and which alter or reverse the magnetism in the magnet of the receiver. It is obvious, say the inventors, that the effect all depends upon the torsion of the small piece of wire, *e*, of thin hardened steel, the pitch and loudness of the sound depending upon the velocity and amplitude of the vibration of the disk, *k*. The inventors have therefore taken four U-shaped steel magnets, and placing their four similar or north poles, N, N, N, N, between the two soft iron rings, W, W' (tapped to fit the thread on A), to polarize the soft iron screw, A; and the four south poles, S, S, S, S, to magnetize the two bar armatures, C, C', by magnetic induction. It is clear that a most intense magnetic field will be set up just at the end of the pole piece, A, and which causes the movement of the armatures to be extremely sharp when the magnetic field is altered by the electric current. The object of the thin ring of leather, *l* (which is fixed loosely so as not to impede the movement of the disk, *k*), is to make the movements of the pine disk air tight. It is not, however, essential, but improves the efficiency of the instrument. A brass ring, H, clamps the thin leather, and it is in its turn secured by the screwed cap, E.

The inventors hold that this receiver is not an infringement of the Bell receiver, not having a plate of iron or steel, but bar armatures, and the disk of wood vibrating not as tympan, but as free vibrator, more approximating to the wood tongue of Reis than to Bell's steel tympan. The other parts will be understood; the nut, T, is for the purpose of regulating the distance between the pole piece and the armatures by springing the magnets open.—*Electrical Review.*





THE BASSANO-SLATER IMPROVED TELEPHONE.

[Continued from SUPPLEMENT No. 491, page 7841.]

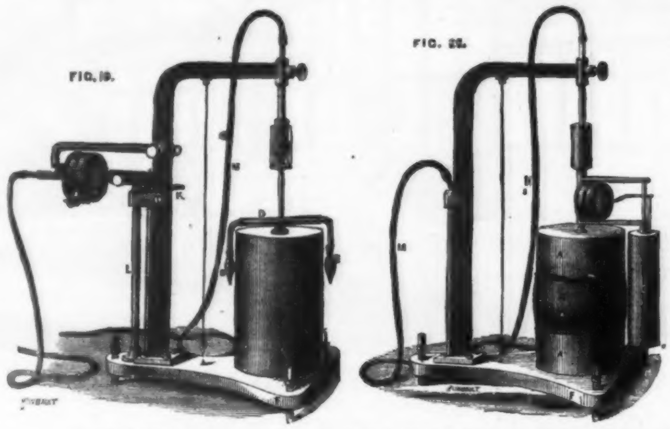
[ENGINEERING.]

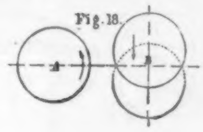
THE HYDRODYNAMIC RESEARCHES OF PROFESSOR BJERKNES.

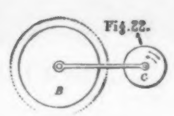
By CONRAD W. COOKE.

3. HAVING considered (1) the effect of circularly vibrating cylinders upon a viscous fluid in which they are immersed, and (2) the effect of one vibrating cylinder upon others vibrating in the same medium, we now have to examine (3) the effect of circularly vibrating cylinders upon pulsating and oscillating bodies similarly immersed; and here again we shall find that a remarkable analogy exists between hydrodynamic phenomena of this class and phenomena resulting from the mutual influence of electric currents upon magnets and of magnets upon electric currents.

From our articles upon Professor Bjerknes' earlier experiments,* it will be remembered that the hydrodynamic analogue of a magnet is a rectilinearly oscillating body, a vibrating sphere for instance, such as is shown at B, Fig. 3, and when mounted, as shown in that illustration (so as to be capable of turning around a vertical axis), the apparatus becomes the hydrodynamic analogue of a compass needle, or of the needle of a simple galvanometer. With reference to this figure we need hardly remind our readers that both the cylinder, A, and the sphere, B, are set into vibration by an alternating air current transmitted by an air-pump to the two parts of the apparatus respectively through the flexible tubes, M and N. If the circularly oscillating cylinder, A, be brought close to the vibrating sphere, B, both being immersed in the viscous medium, the sphere with its frame will rotate around its vertical axis until its axis of vibration lies in a plane perpendicular to that in which the axes of the two instruments both lie. The motions of their proximate surfaces are then in opposite directions, and the position, which is represented in Fig. 18, is one of stable equilibrium. If from this position the frame of B be turned through 180 deg., it will then be in a position of unstable equilibrium, as will be shown by moving it a little to the right or left, when it will immediately return to the position shown in Fig. 18. In this experiment again the hydrodynamic phenomena are inverse to their electro-magnetic analogues, and it is obvious, from what has already been said, that a very perfect hydrodynamic analogy to a galvanometer might by







PROF. BJERKNES' HYDRODYNAMIC RESEARCHES.

produced by constructing an apparatus in which a horizontally vibrating body, such as a vibrating sphere, is inclosed within the space formed by four circularly vibrating cylinders, such as is shown in Fig. 5 and illustrated in the diagram, Fig. 14.

Fig. 19 is a view of an exceedingly apparatus designed by Mr. Vilhelm Bjerknes to illustrate the hydrodynamic phenomenon of the rotation of a pulsating body around a circularly vibrating body, which phenomenon is the hydrodynamic analogue of the rotation of a magnet around an electric current, for, as we have seen in all Professor Bjerknes' experiments, a pulsating or rectilinearly vibrating body is the analogue of a magnet, while a circularly oscillating body represents hydrodynamically an electric current.

Referring to Fig. 19, A is a cylinder which is made to oscillate around a vertical axis by means of the small pulsating drum, H, in connection with the air-pump, by means of a flexible tube, and communicating motion to A by a simple system of levers and rods, of which K and L are visible, while others are below the base of the stand, F F. B B are two little flat bags of flexible caoutchouc of lenticular form, and are attached by the tubular arm, D, to a vertical axis which terminates at its lower extremity in a needle point, resting upon an agate center exactly in the axis of the cylinder, A. The little caoutchouc bags, B B, are caused to expand and contract together by being connected with the pulsation pump by the flexible tube, M, through the air-trap, C. When this apparatus is immersed in glycerine and the pump is set to work, the pulsating bodies, B B, begin to rotate continuously around the cylinder, A, and if the phase of pulsation with respect to the phase of vibration of the cylinder be changed, the rotation will be in the opposite direction.

It is a curious fact that in glycerine or in fluids of smaller viscosity the phenomena illustrated by this apparatus are directly analogous to the corresponding electro-dynamic phenomena, thus forming a remarkable exception to the inverse nature of the analogies illustrated by this research; but it must be remembered that the viscosity of glycerine is not so high as that of several other fluids, and it is probable that this may account for the apparent anomaly; for when a fluid of higher viscosity, such as maize syrup, is employed (thus satisfying more completely the conditions required by theory), the rotation of B is in the normal direction, which is inverse to that of the rotation of a magnet around a current.

Just as in the above apparatus the hydro dynamic analogies of a magnet rotating around an electric current may be produced and studied, so with the apparatus shown in Fig. 20, which is the converse of that illustrated in Fig. 19, the hydrodynamic analogy of an electric current rotating around a magnet may be produced. In this apparatus the circularly vibrating cylinder is replaced by a pulsating cylinder, or, to speak more correctly, by a fixed cylinder, A, having a pulsating zone, B, around the middle of its length, and instead of the pulsating bodies (B B, Fig. 19) there is a circularly vibrating cylinder, C, set into motion by the vibrating drum, H, and free to turn around the vertical axis of the pulsating cylinder by mechanical devices similar to those described in connection with Fig. 19, the two essential parts of the apparatus being connected respectively to the pulsation pump by the flexible tubes, M and N. When this apparatus is set to work in glycerine or in maize sirup, the cylinder, C, rotates

* See SUPPLEMENT, Nos. 488 and 491.

around B in a direction inverse to that of its electromagnetic analogue, so that the apparent irregularity applies only to the case of the pulsating body rotating around the circularly vibrating cylinder. Figs. 21 and 22 are diagrams which will explain respectively the action of the apparatus illustrated in Fig. 19 and that of the instrument last described.

In following the long and very beautiful experimental researches of Professor Bjerknes and his son, two points cannot fail to strike the mind of either the experimental philosopher or the practical mechanician: the first is the extremely ingenious and varied devices by which an alternating (blow and suck) current of air is made to do duty in setting all the various parts of the different instruments into synchronous motion, whether that motion be rectilinear vibration, circular oscillation, pulsatory expansions and contractions, or a combination of several of them together; and the second point is that while such a motive power is theoretically nearly perfect for such delicate experiments, it becomes most severely handicapped in its practical application by the apparently overwhelming mechanical difficulties introduced by making joints and pivots, which, while offering no obstruction to the pulsatory current of air through them, should at the same time introduce no more friction or resistance to minute influences of motion than is offered by the needle point of a compass card. That such extraordinary success should have attended the exceedingly delicate experiments in which an alternating current of air is employed reflects the highest possible credit on Mr. Vilhelm Bjerknes, who devised the apparatus, and upon Mr. Andersen, the resident mechanician to the University of Christiania, who has carried out Mr. Bjerknes' designs with extraordinary perfection of workmanship and constructive ability.

But notwithstanding the great ingenuity displayed in the design, the remarkable skill exhibited in the construction of the apparatus, and the fact that friction and all other disturbing influences have in these instruments been reduced to the lowest possible amount, it must be obvious to any practical mechanician, who is able to appreciate the extremely delicate nature of the experiments, that retarding and disturbing influences, whether of weight or of friction, must in the case of air-driven instruments play great havoc with their sensitiveness, and render it impossible for them to exhibit or even detect many phenomena of the highest possible importance to the research—for, just as a galvanometer needle, heavy in itself, and involving considerable friction in its method of suspension, is unable to respond to certain currents of electricity transmitted through its coils, indicating an absence of current, when in reality comparatively strong currents are flowing around it, so it is equally clear that in the use of the apparatus which we have been describing, all the phenomena exhibited are reduced in their significance by disturbing and retarding influences, and many phenomena, slightly more delicate but equally important, must be lost altogether to demonstration. Thus, electric science, as well in her instrumental defects as in her phenomena, finds her hydrodyamic analogue in the researches of Professor Bjerknes and his son.

[Continued from SUPPLEMENT, No. 498, page 7958.]

[JOURNAL OF THE SOCIETY OF ARTS.]

ON THE CONVERSION OF HEAT INTO USEFUL WORK.*

By WILLIAM ANDERSON, M.Inst.C.E.

LECTURE II.

In my first lecture, I dwelt briefly upon the laws of motion, the principles of work and energy, and the laws of impact. This evening we have to consider several other phenomena, the right understanding of which is necessary before a correct idea of the conversion of heat into useful work can be formed. The theories of oscillation and vibration, involving, as they do, sufficiently high mathematics, might alone occupy the whole of the time I have at my disposal. I must, therefore, deal very briefly with them, although they are so intimately involved in the immediate scope of these lectures. Oscillation or vibration, then, is motion propagated through the substance of a body by short excursions of the molecules of the body to and fro, either in direct lines or in closed curves. A familiar illustration of an oscillating motion is a pendulum; and it is also an instance of the mutual relations between kinetic and potential energies. The moving force is gravity. The bob of the pendulum falls from the highest point to which it has been raised to the lowest point, and in so doing the whole of the potential energy with which it had been endowed, just when allowed to drop, is converted gradually into kinetic energy, and this notwithstanding that its path is not free, but constrained by the rod of the pendulum; but this constraint, according to the second law of motion, does not interfere with the action of gravity. The kinetic energy with which the bob is endowed at its lowest point is competent to carry it again up to the same height as that from which it fell, and in doing so the energy is gradually changed till again it all becomes potential. Were it not for the friction of the attachment of the pendulum-rod, and the resistance of the air, the oscillation, once set going, would continue forever, and at a uniform speed, because the force causing it is constant. In clocks, where advantage is taken of this property of a pendulum, the retarding forces are counteracted by the escapement, a mechanical contrivance set in motion by a wound-up weight or spring, which gives the pendulum a little push during each oscillation.

Let A C, B C (Fig. 10), be the two extreme positions of a pendulum. The force acting on the bob is its weight, represented in magnitude and direction by the vertical line, B G. This force is resolved in the direction of the rod, B F, and at right angles to it, and therefore tangentially to the arc described, B H. Now, because B G is parallel to C E, and H G to C B, therefore the angle β is equal to the angle α. H B, which represents the magnitude and direction of the impelling force throughout the swing, is proportional to the sine of β, and therefore to the sine of α, and consequently to D B. Now if any elastic rod fixed at one end be pulled to one side, the resistance to deflection for moderate distances will be proportional to the amount of deflection or to the length D B, and therefore such a rod, if let go, will vibrate with the same speed as a pendulum; and the general equation for the maximum velocity attained applies to all vibrating bodies, namely—

$$v = \frac{D\,B \times 2\,\pi}{T}$$

Where T is the time of a complete vibration, and D B is half the amplitude of the swing.

Let us take the case of a pendulum beating seconds, its length L in feet will be—

$$L = \left(\frac{0{\cdot}5 \text{ second}}{0{\cdot}554}\right)^2 = 0{\cdot}8145 \text{ foot.}$$

The maximum velocity will be—

$$v \text{ ft.} = \frac{0{\cdot}25 \text{ ft.} \times 2 \times 3{\cdot}1416}{1 \text{ sec.}} = 1{\cdot}5708 \text{ feet per second.}$$

The versed sine D E is the height which the bob falls each half excursion.

$$h = 0{\cdot}8145 \text{ ft.} - \sqrt{0{\cdot}8145^2 - 0{\cdot}25^2} = 0{\cdot}0393 \textit{ ft.}$$

Now, if our reasoning has been correct, we shall find that the potential energy of the bob equals its kinetic. Suppose the bob to weigh 1 lb., the potential energy, in

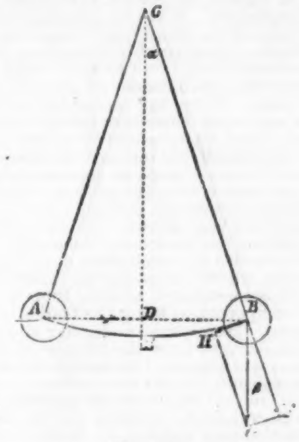


FIG. 10.

the positions A or B = 0·0393 ft. × 1 lb. = 0·0393 foot-pounds. The kinetic energy in the position E, where the velocity is a maximum, and = 1·5708 ft. per second.

$$\text{Kinetic energy} = \frac{1{\cdot}5708^2 \times 1 \text{ lb.}}{64{\cdot}4} = 0{\cdot}0383.$$

The two results are practically identical.

In watches, the pendulum is replaced by a wheel attached to one end of a spiral spring, the other end of the spring being fastened to the framing which supports the mechanism. When the wheel is turned a short distance, the spring is either wound up or unwound, and by that means brought into a state of tension, and then, being set free, the spring restores the wheel to its original position, and in doing so converts the potential energy imparted by the forcible compression or extension of the spring into kinetic energy, and this expends itself in carrying the wheel as much past the neutral point as it had been moved in the opposite direction at starting. This oscillating motion would also continue forever, were it not for the imperfect elasticity of the spring, the resistance of the air, and the friction of the journals; and, as in the case of the clock, these resistances have to be overcome by an escapement actuated by a wound-up spring, which gives the wheel a little push at each oscillation.

Vibrations may be propagated in many ways. Any elastic material may be set into longitudinal vibration. A wire stretched between two fixed points, if rubbed longitudinally, will be set into vibration. The action is of this nature: A portion of the wire rubbed is stretched a little more than the rest by the pull of friction; when the elasticity of the wire overcomes this pull, a portion of wire springs back, and, being elastic, returns beyond the neutral position as far as it was dragged from it. The motion is analogous to what we can see in the pendulum and balance; the elasticity of the material is the moving force. In obedience to the third law of motion, no part of a continuous bar can spring backward and forward without the neighboring sections participating in the movement, and so the oscillation travels along the bar according to well established laws; and because the wave of oscillation causes alternate compression and extension in the bar, it must also cause corresponding changes in its cross section—the bar will be reduced in diameter where extended, and increased where compressed. It is probably to this change of diameter, slight though it be, that we are indebted to the beneficial results of "jarring" anything which fits very tight into a hole when we want to get it out. The sudden alternation from compression to tension in highly elastic and brittle bodies, such as glass, is so intense that they may be fractured into thin slices through being brought into longitudinal vibration by vigorous rubbing.

The mode by which longitudinal vibrations are established and propagated may be very distinctly seen by fastening to some support one end of about a yard of India rubber pipe, and holding it out horizontally, but without stretching it much, with the hand; then, if the end near the hand is well wetted, and the fingers of the other hand rubbed lightly over it, the pulsations will be distinctly felt as they are formed by the alternate catching and releasing of the pipe by the fingers. The vibrations will be propagated along the pipe to the opposite end, and will become apparent as transverse vibrations which result from the sudden alterations of length, due to the pulsations jerking the pipe up and down.

I have here a brass tube fastened securely by its middle to a stout board. Opposite one end is hung a small glass ball; I rub my gloved hand, powdered with rosin, along the rod, you hear a musical note, and at the same time the ball is repelled with violence from the end of the rod. The note is between F sharp and G, corresponding to about 1,400 pulsations per second; therefore, although the excursion of each portion of the rod is but small, the velocity is very great, and hence the sharpness of the blow delivered to the ball.

All solid substances may be brought into transverse vibrations. Familiar illustrations of this are tuning forks, the sounding boards of musical instruments, and

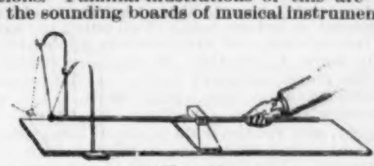


FIG. 11.

stretched strings. When these motions are sufficiently pronounced, they can be seen by the naked eye, but when very rapid and of small amplitude, they can be made to register themselves, so as to become visible, by mechanical means.

Waves are propagated through fluids and gases, such as water and air, much in the same way as along a rigid bar, that is to say, by alternate compression and extension, but the lines of compression and rarefaction extend all round the point from which the impulse is given, spheres of compression being surrounded by spheres of rarefaction, and consequently the impulse travels outward in every direction; and as the energy of motion is imparted to constantly increasing masses, so the velocity of motion is decreased, and the waves become more and more feeble as they recede from the point whence they started. Waves on the surface of a liquid are produced by a similar oscillation of the particles of the liquid, that is to say, each particle describes a curve of elliptical form, the plane being in the direction of motion of the waves, the long axis in deep liquid horizontal. The moving force is usually one acting on the surface, generally the action of the wind; the disturbance is propagated deeper and deeper, the energy of motion acquired at the surface is communicated to greater masses, and hence the motion becomes more feeble, the elliptic paths of the particles

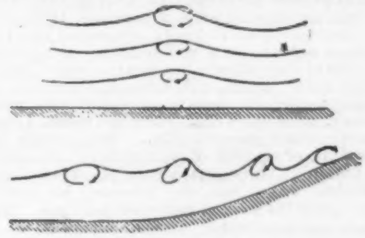


FIG. 12.

become flatter, and at last vanish altogether. In moderate depths, when the bottom is reached, there remains a simple to and fro movement. As water, for example, shoals toward the shore, the lower part of the orbits of the particles is retarded, hence the long axes of the ellipses become sloping, they approach more and more to the vertical, and at last the continuity of the ellipses is destroyed, and the wave breaks in a crest of foam on the beach. The action of the wind in creating waves is analogous to that of friction in producing pulsation in a solid rod, the friction of the air against the water which it slips over tends to move the particles along and heap them up; this heaping up goes on until the weight is more than the friction of the air can support, the mass of water falls, and like the pendulum falls as much below the mean level as it was raised above it. The elliptic motion is due to a combination of the vertical motion produced by gravity and the horizontal motion due to the wind.

Wave motion, like all other oscillating movements, once started would go on forever, were it not that the resistance of the air and friction of the particles of water among themselves tend gradually to bring the motion to rest. The movements which I have described may be plainly seen from any pier in deep water. Looking down on the waves, and observing some floating object, it will be seen to move a little backward and forward as well as up and down, while in shoal water the weeds growing on the bottom are seen to wave to and fro only.

If you watch the surface of the sea, you will notice an infinite series of waves existing at the same time, and being propagated in various directions. This is in accordance with the second law of motion, and you would expect consequently that, if the motion of two waves happened to be in the same direction, the motion of the water would be augmented, and, on the contrary, if the water happened to be in opposite directions it would be reduced, while, in the intermediate stages, there would be a resultant motion depending upon the magnitude and the direction of the other two. This effect is known by the name of "interference" of waves, and may best be studied on the surface of calm water, in which waves may be generated at pleasure. In a calm sea the long smooth rollers, intersected in various ways by minor waves, may also be watched with much profit. It is not alone in water that this interference takes place, but in all cases of vibration, whether in solids, liquids, or gases, the main vibrations are accompanied by minor ones. In musical instruments these minor vibrations are called harmonics or overtones, and to them is due the quality, tint, or *timbre* of the note. The difference in richness of the pure fundamental note and the one accompanied by its overtones is much like the difference between the sea on a very calm day and the sea when a breeze is sweeping over it. In the former case you see only the long, sleepy, oily-looking swell of previous disturbance, in the latter the same swell decorated and rendered brilliant by innumerable systems of wavelets superimposed on the majestic rollers of the swell and on each other. In the same way interference of pulses in the air are recognized by the dullest ear as "beats," that is to say, periods of comparative silence caused by the neutralizing coincidences of regions of compression and rarefaction in the sound wave.

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* Lectures recently delivered before the Society of Arts, London.

As a consequence of the second law of motion, all wave motions are capable of being augmented by fresh impulses communicated synchronously, that is, timed so as to be always in the direction in which the particles are moving, or of being diminished and neutralized by the opposite course. The energy latent in wave motions is small compared to the apparent result produced. Thus, on the sea the friction on the surface of the water of a brisk breeze, having a velocity of thirty feet per second, is but one-tenth of an ounce per square foot, yet the constant and synchronous application of this slight force is capable of raising considerable waves. The power necessary to produce the volume of sound which emanates from a large organ is not more than that which one man working the bellows can easily supply, and yet the flood of sound fills a spacious building, and is even competent to affect it with a perceptible tremor. The lightest touch of a wetted finger on the edge of a tumbler will set it vibrating with exceeding rapidity, emitting a shrill note, while the slight pressure of a feather will instantly damp the vibrations of a piano string.

The last kind of vibration that I have to bring under your notice is that of a mysterious substance, which, for want of a better name, we call ether, which pervades all space and all bodies, whether solid, liquid, or aeriform. It is this ether which links us to the planetary world, for it is the medium by which light and heat are communicated to the earth from the sun and the other heavenly bodies. It must be of extreme tenuity, because it offers no appreciable resistance to the motion of the planets, and, as I have just said, permeates all substances. You may, at first, be disposed to hesitate at accepting a statement that solids can thus be permeated, but we have reason to believe that, looked at with the mind's eye, the densest solid is no better than a very porous piece of sponge. The evidence of the truth of what I have stated lies in the remarkable phenomena of the occlusion of gases in solids and liquids, that is to say, the power which solids and liquids possess of absorbing many times their own bulk of certain gases. Thus platinum, the densest of all substances, occludes as much as five times its own volume of hydrogen without change of bulk; the metal palladium, as much as 643 times its own volume of carbonic oxide. It is, in fact, upon this property that the manufacture of steel from wrought iron by the cementation process depends. In that process bars of wrought iron are packed with substances rich in carbon into iron boxes, and closely cemented in them; they are then exposed to a red heat for many days, during which carbon slowly penetrates right into the heart of the bars. Again, platinum and iron are, at a red heat, permeated by gases to a remarkable extent, that is to say, gases pass right through them. Liquids, again, absorb many gases readily. Rain water takes up 2½ per cent. of its bulk of atmospheric air, and the principle on which the manufacture of aerated drinks depends is that water can, by pressure, be made to hold many times its bulk of carbonic acid gas. At the atmospheric pressure water dissolves about its own volume of the gas, but as the pressure rises, and the gas is reduced in bulk, more gas is absorbed, and it is found that the weight of gas taken up is nearly in direct proportion to the pressure, a relation which the theory of the porosity of bodies would lead us to expect.

Our knowledge of molecular physics is still very limited; the subject is now occupying the attention of some of the most powerful minds of the age; it comes within the province of the chemist, the mathematician, and the physicist, and any theories put forth must satisfy the claims of each. Speaking broadly, I may say that the elementary substances are composed of atoms or particles incapable of further subdivision, and these atoms have each a definite weight, and probably a common specific heat, that is to say, each atom requires the same quantity of heat to raise its temperature one degree. Compound bodies are composed of molecules which are formed each of a definite number and arrangement of the atoms of the elements of which they are composed. Of the structure of the atoms and molecules little or nothing is known, though many bold and ingenious conjectures have been made, but long years will probably elapse before any fully satisfactory theory can be established. The atoms of simple substances, and the molecules of compound bodies, are not in permanent contact with each other. In solids they are in a state of oscillation due to their temperature; this oscillation is analogous to that of a pendulum or watch balance, the forces acting on the particles being mutual attraction and that force which causes the movement which we call heat. Molecular motion, like any other, may be communicated from one body to another, or propagated along the same body, as you saw in the experiment with the brass tube. A body in which the particles are oscillating more vigorously than in another body, if placed in contact with it, will gradually impart a portion of the motion of its own particles to those of the body it touches, and in consequence the motion of its own particles will be enfeebled, because the total kinetic energy of the two substances remains constant.

I have here a light framework from which are hung a number of heavy balls by strings of equal length. I set one ball swinging across the frame; the pull upon its string, due to the motion, sets the top bar of the frame moving synchronously, this motion is imparted to the points of suspension of the other balls, and you see that they all gradually get into swing, and as their swing increases, that of the ball which originated it decreases. This illustrates how heat vibrations are communicated from one body to another, and how the former must necessarily cool in heating that with which it is in contact.

A vibrating string, if it has light substances showered down on it, sets them in motion, but in so doing it has its own velocity reduced. A string vibrating between rigid supports will continue to sound longer than one attached to a sounding-board, because, in the latter case, much more motion is communicated to the air, the sound is much louder, and hence the motion of the string is more quickly damped. The same action takes place in the communication of heat from one body to another by conduction, or from the hotter portion of one body to a colder portion; the rise in temperature—that is, the increase in the amplitude of vibrations of the colder body—is accompanied by a fall in temperature of the hotter. When such increased motion is communicated, the particles make wider excursions, and generally cause the body to expand. At last a point is reached at which the bonds of cohesion have been so weakened by the separation of the particles that they escape from the influence of the other particles they were associated with, and become free to slide over each other, the consequence of which is that the solid substance becomes liquid. In both these states the violence of motion flings off, as it were, particles at the surface, in consequence of which most solid and liquid substances have a characteristic smell, and many of them, such as snow, ice, and sal ammoniac, evaporate with tolerable rapidity, even at very low temperatures. In the case of liquids, the particles in the mass of the substance are in equilibrium, and move indifferently in any direction; but when a free surface is reached, the outward movement has to take place against the force of gravity so soon as any particle tends to rise above the level of the rest, and hence the tendency of liquids to assume a horizontal free surface. Yet from this surface particles are occasionally projected and escape into the air, assuming the form of vapor; and this escape, as might be expected, is more frequent the more rapid the motion of the particles is, that is to say, the hotter the liquid becomes. In gases, the motion of the particles is similar to that in liquids, but more energetic. They move with great velocity in all directions, striking against each other and against the sides of containing vessels, and rebounding according to the laws of impact of elastic substances, which I have briefly explained. It is the continued bombardment of the sides of the containing vessels by particles extremely minute, inconceivably numerous, and gifted with a stupendous energy, due to their high velocity, which produces the phenomena of pressure and temperature of gases. Were the molecules or atoms perfectly elastic, and were there no friction or resisting medium of any kind, there would be no loss of energy, and hence a gas completely inclosed in a non-conducting vessel would never change its temperature. There is, however, one source of apparent loss of energy, and that is that the innumerable collisions among the particles tend to set up very minute vibrations in the substance of the atoms and molecules themselves, and this action would produce the same effect as in the collision of elastic bodies, where I have already shown that the internal vibrations rendered sensible to us in the form of sound are competent to bring the bodies to rest. In the case of gases, the internal molecular vibrations set up would probably not have the character of sensible heat. All gases are supposed to contain the same number of elastic molecules in the same volume, under similar conditions, hence their specific gravities are proportioned to their atomic weights, and their physical properties are also very much alike, that is to say, they obey the same laws of variation of volume and pressure with respect to heat. The space passed through by a particle of gas without collision is termed the free path. There is a difference in the nature and properties of gases in the three following conditions: When in contact with the liquids from which they have become disengaged; when completely separated from their liquids; and again when, at high temperatures, dissociation or a subdivision of the molecules takes place, so that when examining a gas, its condition requires to be defined. The evidence of the truth of the molecular theory of liquids and gases is, that they diffuse into each other, that is to say, two different liquids or two different gases in contact with each other will mix more or less rapidly, which proves that the particles are free to perform excursions of unlimited extent. Mathematical calculations based on these theories enable us to account for the laws relating to the pressure, temperature, and other properties of liquids and gases.

Although the heat and light bearing ether is of the nature of a gas, yet vibrations rendered evident as radiant light and heat do not take place in the direction in which the tangible effects seem to travel, but at right angles to them, like a wave traveling along a string, and these vibrations are extremely complex; they are made up, not only of vibrations of various wave lengths vibrating in the same plane, but of vibrations in planes at right angles and other angles to each other. The waves are of inconceivable minuteness and rapidity of motion, else they could not be expected to traverse solid substances. You are doubtless aware that by means of a transparent triangular prism rays of white light can be decomposed, that is to say, the effect of the form of the prism on a ray from a hot body is to separate the various complex vibrations into ones of definite wave lengths. The visible spectrum is bounded by red at one end and violet at the other, but beyond the red, invisible to human eyes, the heat rays spread out, and beyond the violet equally invisible the actinic or chemical rays. The length of a wave of the extreme red is 39,000 to one inch, and of the violet ray 64,631 to one inch. The velocity of light is 186,000 miles a second, hence the red waves strike the retina of the eye at the inconceivable rate of four hundred and sixty millions of millions of times each second. The analogy between the comparatively coarse motions of sound and those of radiant light and heat is very remark-

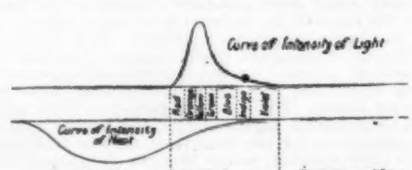


FIG. 13

able, and have, in fact, been the means of leading up to the now well-established undulatory theory. It is well known that musical sounds extend beyond the compass of the human ear, and that ears are not all alike in respect of their powers of hearing extreme notes at either end of the scale; some people, for instance, cannot hear the cry of a bat. The same thing applies to light; we cannot perceive the excessively rapid vibrations beyond the extreme violet of the spectrum, or the comparatively slow movement of the red end, but we can damp the too rapid vibrations by letting the dark rays fall on certain substances, such as sulphate of quinine, and then we are made conscious of fluorescence—light shining out of darkness. You must try and banish from your minds any idea that you may have that there is a substantial difference between rays of heat, of light, or of chemical action. The difference is only one of wave length, and it is due to the structure of our organs of senses that only certain of the vibrations produce the sensation of light, and some of heat, or some produce the impression of light to the eye and heat to the touch. In the case of the actinic rays their superior energy, due to the velocity of motion, may be the cause of their power in decomposing certain substances.

A string made to vibrate, as I have already stated, vibrates in a complex manner, the fundamental note is accompanied by overtones and harmonics; by damping the string in suitable places, the overtones may be extinguished and the fundamental note sounded alone. And so with light and heat. The vibrations in every conceivable plane may be reduced to vibrations in one plane only; this is termed polarization, and as we have seen that sound waves interfere with each other, so do the waves of heat and light. The iridescent colors seen in soap bubbles, and in thin films generally, are caused by the interference of certain wave lengths reflected from the two sides of the film abolishing certain colors, and destroying the usual whiteness of the light by giving prominence to the complementary colors.

The diathermancy of substances, that is, their transparency to heat, is so intimately connected with my subject, that I must devote some time to it. It is a matter of every day observation that substances are endowed with varied degrees of transparency, that is to say, that the undulations corresponding to visible rays make their way among the particles of some bodies, and are arrested in whole or in part by others. For example, glass, water, and air allow the luminous rays to pass with only slightly altered intensity. A certain diminution of energy, indeed, depending upon the thickness of the medium, takes place, as might be expected, from the vibrations having to pass through a crowd of vibrating particles of the substance through which the light is transmitted. Surrounding this monochord, I have placed a tin cylinder with several internal ledges or shelves. It is partially filled with fine

FIG. 14.

sawdust, and as I turn it, the sawdust is showered down upon the string. I now sound the note, and you hear its prolonged cadence gradually dying out. I sound it again, and, at the same time, turn the cylinder; the particles of sawdust, as they fall on the string, are set in motion, and the energy so imparted is deducted from the string, consequently you hear that the sound is quickly extinguished. This is analogous to the effect of radiant light and heat passing through substances, the particles of which are capable of responding to the vibration of the ether, and themselves consequently becoming hot at the expense of the radiant energy.

The experiment with the swinging balls will serve to illustrate this point. When the balls were arranged so as to have the same period of oscillation, you saw that they all got into swing. This would represent the case of an adiathermanous body, which will not transmit radiant heat, and, therefore, gets hot itself. But if I shorten one or two of the strings, and so give the balls a period of vibration which does not synchronize with that of the swinging ball, you observe that they remain quite unaffected; that is the case of a diathermanous substance, which does not get hot itself, but allows the heat rays to pass through.

In the case of light, some substances affect certain wave lengths only and arrest their movement altogether; we then have colored light such as is produced by colored glass, liquids, and gases. A very large number of substances, when they are of appreciable thickness, will not permit the waves to pass at all, and then we have opaque bodies.

The same rules apply to the heat waves, and what we know of light will lead us to expect that the heat wave will be more interfered with by some bodies than others, and that transparency to light need not be accompanied by transparency to heat, and so we find that transparent rock salt is also diathermanous, whereas glass and water very greatly damp the longer heat waves. Gases vary quite as much as liquids and solids in their effect on radiant heat. Atmospheric air, oxygen, hydrogen, and nitrogen scarcely produce any effect on heat waves, whereas olefiant gas and ammonia interfere with them to a very considerable extent.

The remarkable adiathermancy of water is taken advantage of by diamond cutters and engravers, to concentrate a powerful pencil of light on their work without the accompanying heat. Instead of using glass lenses, they use globular vessels filled with water, which act as water lenses, concentrating the light while they completely cut off the heat. I have seen a fire-screen formed by a sheet of water contrived to fall in front of the fire from a slit under the mantelpiece into a trough concealed by the fender.

Our knowledge of the diathermancy of the metals and other substances used in the arts is very limited. Melloni, from whose experiments most of our information is derived, operated mostly on substances more common in the laboratory than in everyday life, but we may safely say that all substances are more or less diathermanous, and that the thinner the substances are, the less the heat waves are interfered with.

We are now in a condition to explain many of the phenomena connected with heat.

First, we will take specific heat. It is a matter patent to our senses that there is a great difference in the physical properties of bodies. They differ in specific weight, in strength, in elasticity, in color, in hardness, and in many other more subtle points, hence we might expect that the atoms or molecules would not be set vibrating with equal facility. We have seen that a force of 10 lb. acting on a weight of 10 lb. will produce a definite velocity in a second of time; but if the force of 10 lb. acts on a weight of 20 lb., the velocity will be reduced to half, and so it is found that a pound of water, the molecules of which are endowed with energy

competent to produce the sensation of 100° Fahr. of heat, if mixed with a pound of water the molecules of which are moving with less energy, and producing the sensation of 50°, the former will lose a portion of their motion while the cold water will gain; the momentum of the two pounds of molecules vibrating at a common velocity will remain the same as the sum of momenta of the respective pounds before mixture, in other words we shall have two pounds of water at 75°. But when the substances mixed together are different, the change of velocity of motion is not so simply arrived at, because not only are the weights of the particles of the two substances different, but the forces which unite them, and which oppose the change of motion, are also different. Thus, if 1 lb. of mercury at 100° be mixed with 1 lb. of water at 50°, the result will be a mixture at 53¼° only, the reason being that the energy of the vibrations in mercury is only about 3⅓ per cent. of that of the molecules of water. This relation of the energy of the vibrations of various substances to water is called the specific heat of the substance. It has been determined with great care for most bodies, and always takes the form of a decimal fraction, water being unity, for it so happens that water requires more heat to raise it a given number of degrees than any other substance. The specific heat of mercury is 0·0333, that of iron 0·1138, that of alcohol 0·615, that of air 0·169, at constant volume. Specific heat in simple substances and in compound bodies of similar atomic composition is found to vary inversely as the atomic weight, that is to say, the product of the atomic weight into the specific heat is very nearly a constant quantity in the elements and compound bodies of the same order, the said product varying in value with each order.

I have stated that water has been constituted the standard to which specific heats are referred; it is time that I should now explain that the quantity of heat or energy of molecular vibrations which raises one pound of water one degree of Fahrenheit is called the British unit of heat, and because it is a fact that energy is indestructible, so heat, being a form of energy, is also indestructible, it cannot disappear or be lost; hence all calculations connected with heat are based upon the supposition that whatever changes of temperature take place, the total amount of heat units involved will remain unaltered in value, though, perhaps, greatly changed in form. By way of illustration, we will take a very convenient method of measuring very high temperatures. It consists in heating a ball of some refractory metal to the same temperature as that which it is desired to measure, and then, with proper precautions against loss of heat, plunging the ball into water. In order to use this apparatus it is only necessary to know the specific heat of the material of which the ball is composed, its weight, the weight of water into which the ball is plunged, and the increase of temperature in the water. Supposing that a ball of platinum weighing one pound had been heated white hot in a furnace, and then plunged into one pound of water at 50°, and that after a time the water had risen to 112°, a simple calculation will show that the ball must have been at a temperature of 2025·3°. The specific heat of platinum is 0·0324. Let us now make what Sir Frederick Bramwell calls a debtor and creditor account. Before the ball was quenched we had the following number of heat units:

In the platinum ball,	2025·3×0·0324×1 lb. =	65·62
In the water	50° ×1 lb.	= 50
Total heat units........		115·62

After the ball was quenched, and had got to the same temperature as the water, we had—

In the water 112° × 1 lb.	= 112	units.
In the ball 112° × 0·0324 × 1 lb. =	3·62	"
	115·62	

You see the account balances, and it is on that expectation that the formula is based by which the temperature of the ball is calculated.

W = weight of water at temp. t being also that of the air.

W′ = weight of ball.

t = temperature of ball before quenching.

t' = temperature of water and ball after quenching.

S = specific heat of ball.

Units of heat in the ball = W′ S × (t – t).

Units of heat after mixture = W (t' – t) + W′ S × (t' – t).

These two quantities are equal to each other, hence it is easy to work out that t', the temperature of the ball when plunged into the water, will be—

$$t' = \frac{(t'-t)\,(W + W'\,S)}{W'\,S} + t.$$

You will find later on that we shall make frequent reference to specific heat.

I have already explained how, when the energy of molecular vibration is increased in a solid, the molecules become emancipated from the rigid thralldom in which they were bound, and the solid becomes a liquid. If still more energy be communicated, the liquid becomes a gas.

Now, in the case of accelerated motion, we have seen that as long as the accelerating force acted, the motion of the body acted on continued to increase; but as soon as the accelerating force was diverted and ceased to act, the motion remained uniform, the effect produced by the force remains, according to the first law of motion, though the force has disappeared. So it is with heat motion imparted to a body. So long as the body heated retains its normal form and properties, we can observe the increase of temperature corresponding to an increase of molecular velocity; but as soon as destruction of form begins to takes place, the increase of heat no longer becomes sensible, the energy of the force is diverted to breaking up the structure of the body, and to keeping its molecules apart and free to slide over each other. When this has been completely accomplished, and not till then, additional energy imparted again produces an accelerating motion, and the liquid gets hotter and hotter, till at last a second boundary is reached, a second destruction of form takes place, and again the rise of temperature ceases till the whole liquid is transformed into a gas, after which acceleration can again take place and the gas further heated, whereby the energy of its molecules, already very high, is still further increased. The heat which apparently disappears during liquefaction and vaporization is said to be latent, which means no more than that heat, like many persons, cannot do two things at the same time. The work of pulling to pieces the structure of a solid or liquid cannot go on if the mercury in the bulb of a thermometer has to be expanded and made to rise at the same time.

If we wish to restore the substances to their original state, we must arrange matters so that the energy which is keeping the molecules of a body apart shall be diverted to heating some other body, in other words we must cool the vapor to make it return to the liquid form, and cool the liquid to make it become solid again.

I have spoken of degrees of temperature very often, and have assumed that you understand that the ordinary mercurial thermometer is a contrivance by which the expansion of mercury in a narrow glass tube enables us to measure changes of heat which affect our senses. The two fixed points in a thermometer scale are the melting point of ice and the boiling point of water, and the space between has been divided, in England, into 180°. Fahrenheit, however, to whom we owe our thermometer scale, had an idea that there was a zero point, a point beyond which temperature could not fall, and he fixed it at 32° below the freezing point of water. Fahrenheit was right in his idea, but quite wrong in the zero point he fixed. We have now better grounds upon which to arrive at what is termed the absolute zero of temperature. A perfect gas is found by experiment to expand or con-

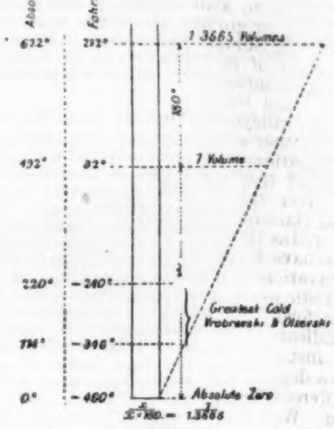


FIG. 15.

tract regularly in direct proportion to the alteration of temperature, and the rate of expansion is such that a volume of 1 at the freezing point becomes a volume of 1·3665 at the boiling point, a range of 180°, so that the volume has increased by $\frac{1}{491}$ part for each degree of rise of temperature. On cooling the gas, it is found to contract at the same rate, so that, supposing it could be cooled 492° below the freezing point, the gas would occupy no volume at all; and this point is called the absolute zero of temperature; it is 492° below the freezing point, or —460° on the Fahrenheit scale. To convert our ordinary degrees into absolute temperature, therefore, we have only to add 460°.

It may be asked whether it is possible that gas deprived of all sensible heat will cease to occupy space; the answer is that we cannot tell. The lowest temperature reached up to the present time has been attained by the Russian chemists Wrobrevski and Olsevski, and is 114° on the absolute scale. The absolute zero of temperature can be arrived at also by other means which it is beyond the scope of these lectures to explain.

THE ERODING POWER OF ICE.

By Prof. J. S. NEWBERRY.

THE geological history of our great and yet largely unexplored continent offers a most important and fascinating subject for observation and study. Many earnest men have devoted themselves to it, and they are making commendable, I may even say, splendid, progress, but the impediments thrown in their way by hasty generalization and unwarranted statement are scarcely less than those which nature has opposed to their progress. We have too much closet geology, too much evolution of theory and system from inner consciousness, and too much dependence upon views seen through other people's eyes. What we want instead is *facts*, and more facts, and still more facts, in order that we may have more real knowledge.

No better illustration of the justice of these remarks can be given than are furnished by the heterodox notions which have been promulgated in reference to glaciers and the glacial period.

The most important heresies, as I deem them, which have been advanced in regard to this subject are: 1. The denial that there ever was a glacial period. 2. "If there was an ice period, it was a warm and not a cold one." 3. "That the phenomena usually ascribed to glacial action in the record of an ice period were generally caused by icebergs." 4. "That ice has little or no eroding power," and "that glaciers have never been important geological agents."

It has chanced to me to have opportunities of studying the record of an ice period and glacial action in different countries, viz., in the Alps of Switzerland, in the Sierra Nevada and Cascade Mountains of California, Oregon, and Washington, in the Wasatch and Rocky Mountain belts and the Canadian highlands, throughout New England, New York, the basin of the Great Lakes and the valley of the Mississippi. Over this wide field I have observed a variety of facts, all tending to prove, as it seems to me, the truth of the conclusion reached by the pioneers and masters in the study of glacial phenomena, and heretofore accepted by the best geologists of Europe and America, viz., that the glacial period was a reality, and that its record constitutes one of the most important and interesting chapter of geological history; second, that this was a cold and not a warm period; third, that ice has great though unmeasured and perhaps unmeasurable eroding power, and that in the regions they have occupied glaciers have been always important and often preponderating agents in effecting geological changes.

I have elsewhere discussed the first three of these propositions, and I now propose to say a few words in regard to the last.

The excavating action of the glaciers of the Alps early attracted the attention of Charpentier, Agassiz, Guyot, and others who were the pioneers in the study of glacial phenomena, and they described in detail and gave names—now everywhere adopted into the language of geology—to the characteristic inscriptions and the masses of debris which are the products of ice action. By later geologists, "*glacial striæ*," "*roches moutonnees*," and "*moraines*" have been discovered and described in various parts of both the northern and southern hemispheres, and the space given to these records in geological literature attests the potency ascribed to ice as an agent effecting changes on the earth's surface. All the most distinguished geologists of the Old World have conceded to moving masses of ice an important role in producing or modifying topography, and one eminent authority, Prof. Ramsay, late Director of the Geological Survey of the United Kingdom, has gone so far as to attribute the excavations of all lake-basins to this cause. In our own country witness has often been borne to the record of powerful erosive action produced by ice; and while the effect of this action has not been accurately measured, it has not until recently been denied.

Within the last few months, however, a number of American geologists have taken upon themselves to deny that ice possesses any eroding or excavating power. Examples of the utterences of this school may be found in Prof. J. D. Whitney's "Climate Changes," in papers by Prof J. W. Spencer on "The Old Outlet of Lake Erie,"* by Prof. W. M. Davis on the "Classification of Lake Basins,"† and the "Erosive Action of Ice,"‡ and remarks on the same subject by Prof. J. P. Lesley.‖

No new facts or original observations are adduced by any of these writers to refute the prevailing opinion that ice is a powerful eroding agent, but they have for the most part contented themselves with the assumption of a judicial attitude and the delivery of a verdict, without a trial of the case.

As one of those who have had some opportunity of studying this question in the field, and one who has committed himself to a view opposite to that now become locally popular, I venture to submit a few facts and arguments which make it impossible for me to accept the recently promulgated views on ice erosion to which references has been made. These naturally arrange themselves under several heads, as follows:

I.—GLACIAL TOPOGRAPHY.

In the Alps the glaciers have done the characteristic work of *local ice streams;* have scoured and filed the bottom and sides of the valleys, forming *roches moutonnees* of all projecting points, and giving to these valleys a simpler and more open section than would be produced by water. Good examples of the contrasting action of ice and water in erosion are given in some of the views in Agassiz's "Etudes." The broad valley with planed sides, the work of ice, is cut at bottom by a deep and narrow channel formed by the flow of the stream which drains the diminished glacier.

In the mountains of Oregon a remarkable monotony of surface has been produced by ice action. The crest of the Cascades, crowned by the volcanic peaks, Mt. Jefferson, Mt. Hood, etc., has sides sloping east and west like the roof of a house. These slopes are planed down, and their asperities removed; everywhere showing the effects of a powerful grinding agent. Where a rough volcanic ledge once rose above the surface, only a remnant of it now remains in a *roche moutonnee* or a low ridge like a boat bottom, its top and sides smoothed over or beaded, as a plasterer beads a cornice, by the moving ice under which it once was deeply buried. From the great crater in the center of the group of snow peaks called the Three Sisters, the courses of ancient glaciers can be traced far down the mountain sides by the polished or deeply furrowed surfaces of the hard volcanic rock which composes the mass of the range. In the Sierra Nevada, the Wasatch, and the Rocky Mts. similar inscriptions are visible in innumerable localities. Slopes are ground off, the outlines of the mountains rounded, the valleys broadened, their sides and bottoms smoothed as they could only be by the removal of a vast amount of material.

In the Laurentian belt north of Lake Huron, Lake Ontario, and the St. Lawrence, where were formerly high mountains are now only low hills and rolling surfaces. Over hundreds of square miles the rock is mostly bare, consisting of strata of granite, slate, dolomite, diorite, etc., standing at high angles, but planed down, scratched, and ground by glaciers until their cut edges are like the boards in a floor.

In the interval between the Hudson and the Connecticut, layers of crystalline rock of similar character stand on edge, the arches so truncated by erosion that it is almost impossible to analyze the section. Here also the edges of the granite, slate or marble layers are ground down into a plane or rolling surface. Here, too, as in Rutland County, Vermont, and many places where the strike of the strata has been nearly in the line of the glacial movement, the softer beds, as slate and marble, are scooped out into ice-worn and glaciated valleys, the harder strata left in relief on either side. Where the whole face of the country has been ground off, and nothing is left to mark the original level, it is of course impossible to measure the amount of erosion produced by ice; but where we find broad, straight, glaciated troughs scooped out of the softer rocks in the line of glacial motion, we have evidence that ice has done most, if not all, of the erosion; and facts of this kind are sufficiently numerous and striking to furnish in themselves a refutation of the statement that ice has no eroding power.

Any one who has any knowledge of surface geology knows that the action of running water on topography

* 1 Proc. Amer. Philos. Soc., Vol. xix., p. 300.
† 2 Proc. Bost. Nat. Hist. Soc., Vol. xxi., p. 315.
‡ 3 Proc. Bost. Nat. Hist. Soc. Vol., xxii., p. 19.
‖ 4 Proc. Amer. Philos. Soc., Vol. xx., p. 95.

is not only different from that of ice, but antagonistic to it. Water falls in rain from the clouds, is immediately gathered into *lines* of drainage, and there it expends its power in deepening such lines and increasing the asperities of the topography. The canons of the Colorado are typical and characteristic illustrations of water action on continental surfaces. Great ice sheets, on the contrary, tend to reduce all asperities, fill depressions, and render the topography monotonous. Since water has fallen from the clouds in all ages and over all portions of the earth's surface, while ice has been local and temporary, it is true that the aggregate amount of erosion produced by water is much greater than that caused by ice, but over equal areas and in equal periods of time the erosion of ice is far greater. This is illustrated by the difference in the water of the streams which drain glaciers and those which drain adjacent valleys in which there are no glaciers. In the first it is always opaque from the sediment it carries; in the other, generally transparent from its purity. Good examples of this contrast have recently come under my observation in the streams which flow down the west slope of the Cascade Mountains in Washington Territory. Of these, the Cowlitz, Pyallup, White River, etc., drain the glaciers of Mt. Tacoma, and are always turbid and opaque from the amount of fine eroded material which they carry. The others, fed by rains only, are clear. Two branches of the Dwamish are called respectively White and Black rivers, because one, flowing from a glacier and loaded with sediment, is always milk white; the other, draining an equal area and having about the same volume of water, is transparent or slightly colored with carbonaceous matter. The contrast in the color of these streams where they join, has suggested the names given them.

In the Alps the turbid, milky water of the streams which drain the glaciers is recognized as characteristic, and it is called *gletscher milch* by the German-speaking Swiss. The finer part of the sediment of such streams, transported to great distances in virtue of its fineness, causes the peculiar opalescence of the Swiss lakes. This fine and far-carried sediment constitutes but a part of the material eroded by glaciers; the coarser part being left behind as bowlders, gravel, and sand under the glacier, where they are its cutting tools, or as lateral and terminal moraines. Yet the measurement of the finer half of the glacial grist, flowing off in the draining streams, gives striking proof of the eroding power of glaciers and the error of those who deny it. For example, the stream which drains the Aar glacier carries away daily 280 tons of sediment, and the Justedal glacier of Norway wears down and removes 69,000 cubic meters of solid rock annually *—and these are only partial measurements of the eroding power of two small glaciers.

The Champlain clays of the Atlantic coast represent the fine flour ground by the glaciers when they covered New England, and when a thousand milky streams ran down to the higher-standing sea, and deposited their load of sediment in the first dead water that checked their flow. The coarser products of glacial erosion are left in Kames, and Eskers, or sheets of gravel, sand, and bowlders on the higher lands. It is probable also that the loess of the Missouri Valley, as well as that of the valleys of the Rhine and Danube, was the deposit of sediment-loaded, ice-cold streams, which drained the greater glaciers of the Ice Age.

At the meeting of the American Association in Minneapolis, last year, Prof. J. P. Lesley reiterated his oft-made assertion, that the erosive power of ice is insignificant, and wrote out a table on the blackboard in which the erosive power of pure ice was set down as 1, that of pure water as 10, that of acidulated water as 100, that of ice set with stones as 1,000, that of water carrying stones at 10,000.

No facts were cited to support these statements, perhaps for the reason that none are known which warrant them. It is not too much to say that they were not based on any trustworthy observations, and that the figures given in the table cited were mere figments of the imagination.

II.—THE DRIFT DEPOSITS.

The most conspicuous and indisputable proof of the erosive power of glaciers is given by the vast amount of material which they have ground off or detached in one place, transported, and deposited in another. The sheets of bowlder-clay which cover so much of the glaciated area in our own and other countries are nothing but this ground-up material remaining where and as the glaciers left it; and the great heaps of coarse morainic matter, beds of sand, gravel, and bowlders, which occupy so much of the highlands, as well as the sheets of Champlain clay below, washed out of such debris, supply the most striking and convincing illustrations of the error of those who claim that ice is a protective rather than a destructive agent. South and west of the Canadian highlands is an area of not much less than 1,000,000 square miles, which is covered with glacial debris. I have elsewhere estimated it to be 1,000 miles long and 500 miles wide, but it really occupies nearly twice as large a space, since it extends from eastern Newfoundland around to Cumberland House, at the head of Lake Winnipeg, and probably to the Arctic Sea, 1 000 miles further. The Banks of Newfoundland, George's Banks, and Cape Cod constitute its eastern margin. Its southern limit within the United States has lately been carefully traced by Upham, Lewis, Wright, and Chamberlain. Dr. George Dawson and Dr. Scudder have told us something about it in Canada. No geologist has followed it further north than Cumberland House, but Capt. Back, Dr. Ray, and Sir John Richardson have incidentally described topography and superficial deposits of more northern regions, which we must consider as of glacial origin.

It has been said that the northern part of British America is without evidence of glaciation, and this has been urged as an argument against an ice period; but I venture to predict that when that region shall be traversed by experienced geologists, they will find conclusive evidence of general, if not universal, glaciation. An unskilled observer might not detect any sign of the former presence of glaciers where he could not discover glacial scratches on the surface rocks, but such marks are often invisible over areas which have certainly been occupied by glaciers. *Exposed* surfaces of most rocks disintegrate so rapidly that they will not long retain glacial marks, and it is only when a country is occupied by man and the protective covering of clay, sand, etc., is locally removed in roadways, railroad cuts, canals, cellars, etc., that the buried inscriptions are brought to light. *Glacial deposits* are, however, quite as conclusive evidence of the presence of glaciers as glacial striæ. Moraines, Kames, Till with striated pebbles and bowlders, and barrier lakes are all trustworthy witnesses; and it may be said that banks of clay containing disseminated pebbles and bowlders, even if these are not striated, must be referred to ice action, as flowing water sorts the materials transported by it, leaving the bowlders in one place and the clay in another, or the two in distinct strata deposited in different conditions as regards the depth and movement of the water. In the Yellowstone Park I found no glacial striæ, but moraines and glacial lakes proved that the valleys had once been occupied by glaciers of great size; and the party of Mr. Hague, in their longer stay and more extended explorations, found abundant rock inscriptions made by the ice. So in Puget Sound no rock is seen in place over a great area, but I took striated pebbles from the bowlder clay at Tacoma, Port Townsend, and elsewhere; and when rock is reached on Vancouver Island, ice-cut grooves and planed surfaces everywhere abound; and these coming up out of the water show that the basin of the Sound was once filled with an enormous glacier.

In New York, Ohio, Illinois, etc., the sheet of glacial debris is estimated to have an average thickness of from 30 to 50 feet, of which the smaller figures are quite within bounds. Probably half of the original mass, perhaps much more, has been washed away during all the thousands of years which have elapsed since the melting of the glaciers. Rain and rivers with their boasted eroding power have been steadily at work on it, and yet this residual sheet is vast enough in its proportions to afford a complete refutation of the statements of those who would ignore or belittle the power that has produced it.

III.—THE EXCAVATION OF LAKE BASINS.

Generally modified typography, truncated mountain ranges, and half a continent covered with glacial debris constitute such stupendous monuments of the eroding power of ice that the question of its ability to excavate lake basins requires no discussion. The power which has done the greater work is certainly equal to the less. Just how far ice is to be credited with the excavation of lake basins is, however, a matter which may fairly give rise to a difference of opinion. In my discussion of the origin of our great lakes in the Report of the Geological Survey of Ohio, I have considered them as expansions of river valleys caused by local glaciers, which, in the advance and retreat of the great glacier that filled and buried the lake basins, occupied the pre-existent valleys and locally broadened and deepened them. Other writers have either denied to glaciers all participation in the excavation of lake basins, or have limited their action to the formation of moraine dams in river valleys. It is abundantly proved, however, that glaciers have occupied the basins of our great lakes, as well as the elongated lakes of the State of New York, and have done something, perhaps much, to effect their excavation. Moraine dams, which are among the characteristic products of glacial action, have certainly helped to form many water basins, but all the facts known indicate that most of our lakes are in rock, and in some instances are excavated, in nearly horizontal strata to a depth of many hundred feet, by some agent which differed greatly from running water in its mode of action. We shall need to probe the earth banks which border Lakes Michigan, Huron, Ontario, and the smaller lakes mentioned, before positive and quantitative assertion can be made on this point. But there is certainly no proof that these profound excavations have ever been drained to their bottoms by flowing streams. That there are elsewhere many rock-lipped basins which have been excavated by ice is abundantly proved. The Scotch lochs, the rock basins of Norway, described by Whitmell, and those mentioned by Penck as existing at the mouths of the old glacial valleys of Bavaria, afford abundant demonstration that ice can excavate and has excavated lake basins. Unfortunately, most such basins are filled with water or debris, and full examination of them is impossible. Lake Saltonstall, in Connecticut, is a rock-rimmed basin excavated in the Triassic sandstone, and, in my judgment, is the work of ice.

That our lakes are not generally the result of local elevation or subsidence—warping of the earth's crust—all those who have carefully examined their surroundings are agreed. Lake Superior alone lies in a synclinal fold, and that has been largely excavated. That our lakes were for ages occupied by glaciers, which moved in the direction of their major axes, and protruded beyond their rims, spreading around the lower end of each a fan-shaped moraine, was shown by the writer long since, and has been more fully demonstrated in the masterly reports on the geology of Wisconsin by Chamberlain and Irving. But the suggestion that the ice masses by which they were filled were sufficiently heavy to cause a subsidence of their beds and thus a depression of the earth's crust is untenable, since the weight of the ice, however thick, could never have been half that of the rock that has been removed from them. Aside from this, such subsidence would give a synclinal structure to the troughs, of which we find no traces in those which are among the deepest of the series, Michigan, Huron, and Ontario.

In this connection I would again call attention to the facts that our chain of great lakes holds a peculiar relation to the arch of the Canadian highlands, and that beyond Superior a continuation of the series reaches to the vicinity of the Arctic Ocean. While no positive assertion would be warranted without a thorough exploration of this boreal region, we may at least suspect that its larger lakes will be found to bear, like those nearer home, unmistakable marks of glacial action; and that they are, like our lower lakes, old river valleys which have been locally occupied, broadened, and deepened by glaciers.

Prof. Lesley said at Minneapolis that our great lakes were valleys similar to those of Pennsylvania, etc., south of the Drift area, but they are radically different. The Pennsylvania valleys are troughs between ridges formed by faults and folds, while most of the lake basins *are excavated in nearly horizontal strata.*

In the most important contribution that has been made to the subject of Quaternary glaciation since the study of the Swiss glaciers by Agassiz, Guyot, etc., "The Glaciation of the German Alps," by Dr. Albrecht Penk, of the University of Munich, the eroding power of glaciers is illustrated by a great number of striking facts; for example, the residual debris of glacial action now spread over the Bavarian plateau is estimated by Penk to be equivalent in quantity to a sheet of rock 36 meters in thickness over the entire northern Alps. Penk also credits the excavation of the most important lake basins of the regions he studied, the Ammer See, Wurm See, etc., to glaciers, and also states that a lake basin filled with water or sediment lies at the mouth of each of the Alpine valleys through which glaciers protruded in ancient times.

MODE OF GLACIAL EROSION.

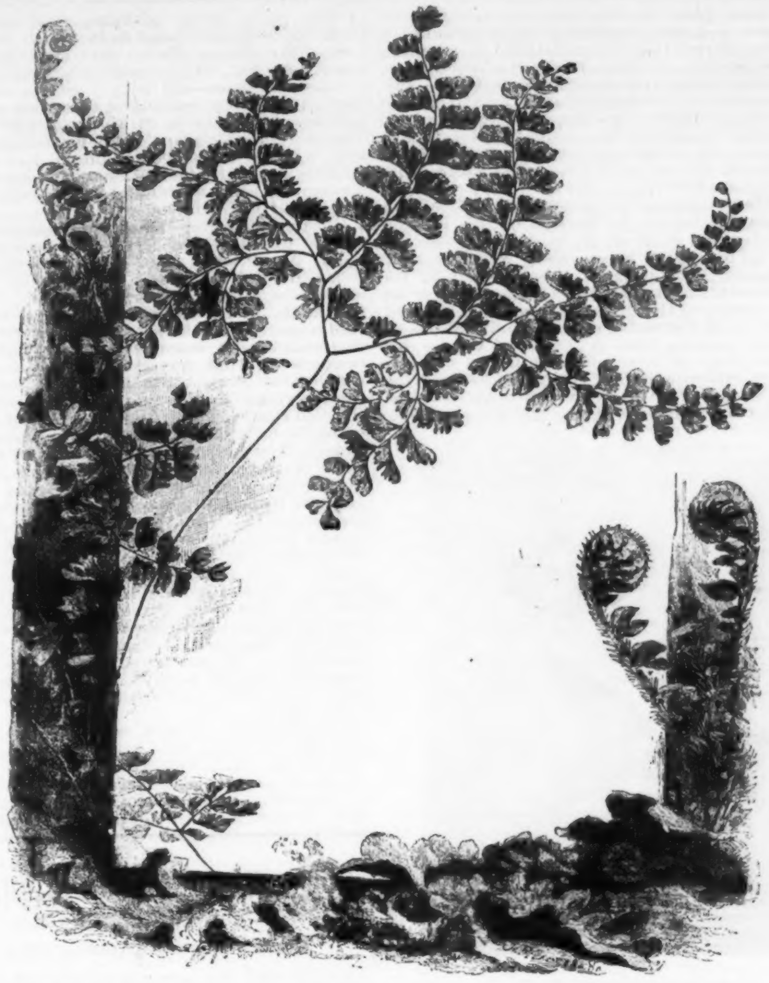
Probably much of the misapprehension which has existed in reference to the erosive power of ice is due to the fact that the composition and action of a glacier have not been understood. It is perhaps regarded as a mass of pure ice, which by itself would have little grinding power; but a glacier is a great moving mass, which by its weight and motion crushes and removes all but the most solid rock prominences over which it passes. Where it impinges against cliffs, these are sometimes lifted, and huge blocks are carried bodily away. In many localities we find stones hundreds of tons in weight, which have been torn from their beds and carried many miles. Pure ice, then, in sufficient volume is a potent and almost irresistible agent of erosion, quite independent of its grinding action, but as a matter of fact all glaciers are studded below with rock fragments, great or small, which they have torn up in their course; so that sand, gravel, and bowlders constitute a coating to the under surface of a glacier, which may be compared with the emery on a copper wheel. The efficiency of such an eroding agent may be in part realized when we reflect that the great glaciers which covered so much of our country had a thickness of from 1,000 to 5,000 feet, and hence that the sand and gravel beneath them was pressed upon their beds with a force of from 50,000 to 250,000 pounds to the square foot. Such a moving mass would not only be capable of sweeping away any ordinary barriers that opposed its progress, but would grind down the underlying rock with a resistless and comparatively rapid action. In a country completely covered with an ice sheet and worn down simultaneously in all parts, we have of course no direct means of measuring the amount of erosion produced; yet when we find the residue of the glacial debris, perhaps not more than half of the original mass, covering nearly a million of square miles adjacent to the Canadian highlands, we have a witness to the potency of ice action which is sufficiently impressive.

Prof. Lesley has attempted to measure the erosion of glaciers by the record of glacial action shown on the Kittatinny Mountain. He represents the rock removed from the summit to have been 70 feet in thickness, and makes this the basis of a general estimate, but he does not seem to have considered that this was just on the margin of the ice sheet, at the period of its greatest extension, and where its stay was shortest. One hundred miles further north the ice was probably ten times as thick, and its erosive action was perhaps continued through ten times as many years. This would give it an efficiency perhaps one hundred times as great.—*School of Mines Quarterly.*

NORTH AMERICAN FERNS.

THESE are mostly valued for their hardiness and usefulness, producing as they do in the out of doors fernery a contrast which could not be obtained by planting British species and varieties alone. Some of them, too, are individually interesting. Such is the case with Adiantum pedatum, the principal figure in the annexed illustration. North America, even with all its numerous ferns, produces only three adiantums, viz., A. capillus verenis, A. emarginatum, and A. pendatum. The first two are not hardy, but A. pedatum in its native country will stand over 30° of frost, protected, however, by a thick layer of leaves, which naturally cover its crowns when at rest, and annually also by a thick coating of snow. It is quite distinct in habit and general appearance from any other Adiantum. It is extensively distributed, being met with in abundance from New Brunswick and Canada to Alabama, and it is also found in Utah, Oregon, California, British Columbia, Wisconsin, Arkansas, etc. It is very plentiful in rich moist woods, especially among rocks. In such places it forms patches under trees, often covering several acres at a stretch. In growth it is very peculiar, its singularly pedate fronds, which are pea-green in color and which are very fragile, are borne on dark purplish shining stalks, and are produced from the extremity of long underground rhizomes, which through the annual fall of leaves and their accumulation often lie buried under six inches deep and even more of decaying vegetable matter, which the fronds have to get through before they can reach the surface of the soil. According to eye witnesses, such masses of a pedatum are a grand sight. If in some places in England failure has attended the attempt to cultivate it outside, the failure is due to the fact that the underground rhizomes are generally too close to the surface, and that they are neither protected in winter by leaves nor snow, and thus feel more keenly the effects of cold, though less severe than that of its own country. Another North American fern of great beauty and possessing characters strikingly different from any of our own is the Onoclea sensibilis. It occurs in a wild state in meadows from New Brunswick to Saskatchewan, and southward through Kansas and Arkansas to Louisiana, and eastward to Florida. It is particularly interesting owing to its mode of fruiting being essentially different in that respect from all other known ferns. It fertile fronds, which are only a few inches high, are produced very sparingly and are totally distinct from the barren ones. They are perfectly erect, very rigid, and remain on the plants for a couple of seasons; whereas the barren ones which on account of their soft, pale, pea-green color, may be considered as the most attractive part of the plant, are quite deciduous and triangular, with the edges of pinnæ beautifully undulated. They measure, when the plant is well established, as much as from 18 inches to 20 inches in height. Then there are the Osmundas, which, although met with in all parts of the world, have their most distinct, as well as most decorative, representatives in North America. From

* Geikie, Geological Text-Book, p. 418.



THE NORTH AMERICAN MAIDENHAIR FERN (ADIANTUM PEDATUM).

Java and from Hong Kong we have O. javanica and O. bipinnata, two evergreen species; from Brazil comes O. palustris, also an evergreen kind; but all other known species or varieties partake of the deciduous character peculiar to the British Royal fern. The three North American kinds already in cultivation are all well worthy of special attention, for they are essentially distinct from all other osmundas, and all of them are of a highly decorative character. O. cinnamomea is the strongest grower of the three, and it is also the one whose fronds are endowed with the greatest resisting powers. It is found in great abundance in low grounds and moist copses in Newfoundland, Louisiana, and Florida, etc. Although very ornamental in its barren state, it is when fertile that it cannot possibly be mistaken, as the fertile fronds, which are erect and of a cinnamon color, are produced only after the barren ones are perfectly unfolded. They rise from the center of the plant and form its principal attraction. O. claytoniana, better known in Europe under the name of O. interrupta, is a species as curious as it is ornamental. Its fertile fronds do not bear the fructification throughout, but only in parts of its length, hence the name interrupta. The outer fronds, which are first produced, are exclusively sterile; the fertile ones, which are produced later on, rise from the center of the plant, and are of a much more erect habit than those perfectly barren. The lower part of their leafy portion is barren, then about eight to ten pairs of fertile pinnæ are situated toward the middle of them; and finally their extremity for about from twelve to fifteen pairs of pinnæ are barren again, an arrangement which renders this one of the most conspicuous and curious kinds known in cultivation. It is also distinguished from all other Osmundas by having a little tuft of wooly hairs clinging to the axle of each pinna of the barren fronds. It is very common from Newfoundland to Lake Superior, and its natural habitat extends to the mountain regions of Arkansas, Kentucky, and North Carolina, if not even further. O. spectabilis, also from the same regions, is totally different from either of the two above described species. It is of dwarfer habit, rarely exceeding 15 inches in height, and its fronds are much finer cut and of a beautiful purple hue when young, gradually changing to a metallic color and then to a pale green, just as some of the Maidenhair ferns do. The fronds are erect, or nearly so, close together, and bear their fertile portion on their summits. There are no exclusively fertile fronds in this species; all mature fronds bear more or less fructification, which is ripe before the frond on which it occurs is perfectly developed and hardened. There are also in North America several kinds of Nephrodium, which are found extremely useful in this country. N. floridanum is one of the most striking of all ferns from that part which stretches from Florida to Louisiana, where it is found growing mostly in wet woods where there is a good depth of vegetable matter. N. nevadense is a fern which, were it not for its peculiar characters, would not have received much attention at the hands of our home growers on account of its general aspect bearing a certain resemblance to that of some of our own ferns; but a most important feature to be observed in its fertile fronds, and one which has not been found in any other fern either from the New World or the Old, consists in the divisions or leaflets being folded together early in the day and opening only late in the afternoon. Another constant character also peculiar to this curious species is that the entire surface of its fronds is copiously dotted all over with minute shining globules of a resinous character, producing a most peculiar effect. It habitat is very local, being the Sierra Nevada and Northern California. N. noveboracense is particularly attractive, owing to the fragrance of its fronds, especially when not fully developed. It is a species of medium growth only found in moist meadows in New Brunswick and Canada to Virginia; also in Ohio, Kentucky, and North Carolina. Its fronds, which are rather brittle, are of a pale pea-green, a color which is retained throughout the season, and their fragrance is such that a few of them dried in the open air perfume a room deliciously for a long time. Polystichum munitum is another striking North American fern which can be grown successfully in this country without any shelter. Its fronds, which are hard, are of a beautiful dark green, peculiarly serrated on the edges of their pinnæ, and may be counted by scores. It is very abundant in San Diego, California, northward to Columbia and Southern Oregon, where it grows from four feet to five feet high, and is highly ornamental on account of the dark hue of its hard and lasting foliage, and of its stalks, which are very chaffy. Aspidium Goldianum has no resemblance whatever to any European fern, and is therefore valuable, forming, as it does, by its broad and somewhat loose foliage, a very good contrast with other kinds which one generally sees in out-of-door ferneries. It is a strong grower, its fronds reaching, when in a good situation, as much as 3 feet in length. It grows abundantly in rocky woods from Canada and Maine to Indiana, Virginia, and Kentucky. Struthiopteris pennsylvanica, though in many respects resembling the European S. germanica, is a fern of more noble aspect and much larger dimensions. It is met with in abundance from the Saskatchewan and Lake Winnipeg to New Brunswick, and southward to Pennsylvania and Illinois. In all these parts the ostrich fern is considered one of the finest of the North American ferns. The outline of the whole plant possesses the same peculiar vase-like shape noticeable in European species. Lygodium palmatum, one of the most distinct as well as one of the most charming of all known species, is a lovely climbing fern. Many more interesting species just as hardy as any of our own native kinds belong to North America, but the above selection will give a fair idea of their value as regards the ornamentation of out of door ferneries in this country.—*S., The Garden.*

ANCHOMANES DUBIUS.

ANCHOMANES DUBIUS is one of those striking aroids which from a thick, fleshy tuber send up, first a spadix, and afterward a large, stalked, much cut leaf of much beauty. The inflorescence here figured is remarkable for its singularly delicate and unusual coloration, the outer surface being pale olive-purple, the interior glossy cream-colored. The spadix is covered for five-sixths of its length with densely packed cream-colored male flowers, the lower sixth with dull purple female flowers, each consisting of an ovary only, turned downward and destitute of perianth. The pollen grains are elliptic, granular, mixed with needle-shaped raphides. For the connoisseur this is a grand plant, and we thank Mr. Bull for affording us the opportunity of figuring it. —*The Gardeners' Chronicle.*

LIFE AT THE BOTTOM OF THE SEA.

THE organization of fishes that live at great depths is identical with that of animals that inhabit the coast. The organs of respiration, digestion, and circulation exhibit no special peculiarity of structure and no important modification. As Mr. Vaillant has said, "under these enormous pressures the same organic systems that we find in beings that inhabit the most superficial zones suffice for the accomplishment of the delicate reactions that the gaseous changes necessitate, the modification of alimentary substances, and the other phenomena of life." Consequently, on coming to inhabit the bottom of the sea, fishes have merely adapted their organism to peculiar conditions of existence. The causes that led to such adaptations were multiple.

To the light that penetrated the upper strata of the sea succeeded greater and greater darkness, the agitation of the waves raised by winds was replaced by an

ANCHOMANES DUBIUS: SPATHE PURPLISH OUTSIDE, CREAM COLORED AND GLOSSY WITHIN.

eternal calm, and high temperatures gradually became lower.

The absence of light appears to have brought about the most remarkable transformations in fishes. We have long known that fishes that live in profound darkness lose their sight. Thus, there exists in the Mammoth Cave, in Kentucky, a very strange fish, the *Amblyopis speleus*, in which the sense of sight has entirely disappeared. The organs of vision no longer operate, and the skin has grown over and covered them. In the presence of this fact we should expect to find that fishes taken from a great depth were blind; but such is not the case, for those that are taken from a depth of 15,000 feet have perfectly normal eyes. The existence of these animals in a dark medium, with eyes like those of surface fishes, seems, consequently, at first sight, impossible to understand. It was not until it was found that fishes were capable of secreting a luminous mucus adapted for lighting to a great distance, or rather that they were provided with plates that gave off a phosphorescent glow, that this fact was explained.

In the *Malacosteus niger* there exist beneath the eyes two phosphorescent disks, one of which emits a golden and the other a greenish light. This fish was found in great abundance in the first place off the coast of the United States. During the expedition of the Talisman it was brought up off the coast of Morocco from a depth of 4,800 feet.

Another fish, the *Stomias boa*, (Fig. 2), exhibits a different arrangement of luminous organs. The sides of its body are provided beneath with a double antero-posterior row of phosphorescent disks, which, emitting a light, cause the fish to be surrounded with a brilliant luminous aureola. This fish must be much dreaded by the inhabitants of the ocean bottom. It is constructed and armed for fighting. Its long sharp teeth must serve it for attacking redoubtable adversaries, and of biting and lacerating them. The individual represented, which is about twelve inches long, was taken in the Gulf of Gascony at a depth of 6,200 feet. In other fishes of deeper water, it would seem as if the property of emitting light were much diminished, or were wholly wanting. The sense of sight in this case would only be called on to operate at the moment of meeting an animal transformed into a source of light.

The *Bathypterois longipes*, Gunth. (Fig. 1) appears to be in this condition. In this fish, which abounds in the Atlantic at depths of from 2,500 to 4,800 feet, no phosphorus disks are found upon any part of the body, and the glandular system which secretes a luminous humor is not developed. The eyes, on another hand, are very small in comparison with the fish's size, and, consequently, in nowise comparable with those of the *Stomias* just mentioned. In view of this relatively inferior organization, it would seem as if the *Bathypterois* would have great trouble to secure an existence amid the profound darkness that prevails around it. But nature has fortunately come to its aid by adapting a part of its organism to special biological conditions.

When we examine one of these animals, we are surprised at the form and arrangement of the first pair of fins. In ordinary fishes we see that this organ of locomotion consists of different rays connected together so as to constitute a blade for striking the water. This is not the case in the *Bathypterois*. The pectoral fin consists entirely at its upper part of a very long ray which is entirely independent of the rest of the rays that compose this organ. In the case of this extraordinary development of the upper part of the pectoral fin, we are led to inquire what need, what function, does it subserve? Upon more closely studying the mode of articulation of this appendage, we soon see that it is so arranged that it can be pointed forward, and then we grasp the sort of modification that has occurred in this deep sea fish. A portion of the fin has been diverted from its functions, and it has come to constitute an exploring organ. When the *Bathypterois* is moving forward, it advances these two long, antennæ-like tentacles and feels with them, and the sensations that they transmit to it warn it of the presence of prey that it may capture or of a formidable enemy that it must endeavor to escape from. They must likewise serve it for exploring the mud and discovering therein the worms and annelids that inhabit that substance.

The ventral fin exhibits a similar transformation of its anterior ray, but the dimensions that this has acquired are much less.

On figuring in the imagination an image of submarine life, and of the struggles for existence that are ever occurring at the profoundest depths, we are led to ask which are the animals that have the most perfect adaptations? Is it the superb *Stomias* sparkling with light, the *Malacosteus* with its beacon lights in the front of its head, or the dark *Bathypterois* that has succeeded in securing life in a more certain way? It may be the latter. Its long tentacles, like sticks in the hands of a blind man, permit it to know what surrounds it, and to find food; while its eyes, still intact, allow it to see the approach from afar of a dangerous enemy all surrounded with the light that emanates from its body. It is capable of taking flight at the moment of peril without leaving luminous traces of its passage, and of quickly disappearing. It may be, then, that protection to life at the bottom is more particularly secured to the less brilliant.

If, from a general point of view, we endeavor to sum up what submarine explorations have taught us in regard to the nature of deep sea fishes as compared with those of the surface, we shall find that at between 200 and 600 fathoms there exist forms that are closely allied to those of the superficial zones. The representatives of that great group of fishes that naturalists call chondropterygians—animals in which the skeleton is formed of cartilage (sharks, rays, etc.)—descend to only about 4,800 feet. The acanthopterygians—fish having a bony skeleton—are largely represented at great depths. The representatives of surface genera appear to descend only as far as to from 4,000 to 4,800 feet. The acanthopterygians, made for living at depths of from 4,800 to 18,000 feet, belong to special genera, as appears from the observations of Messrs. Günther and Vaillant on fishes during the explorations of the Challenger and Talisman.

During the greater part of geological time the earth's surface did not exhibit those deep depressions and great projections that it does in our day. The continents did not possess their present great reliefs, or the oceans their abysses. Gradually, in measure as the earth, under the influence of the cooling that it continuously underwent, cracked, the bottom of the oceans sank more and more. The equality of temperature that was established between the deep marine zone of the warm and temperate regions and the superficial marine zones or those of slight depth of the cold regions permitted species living at these latter points to extend over greater and greater spaces; although they met with conditions of life different from those of the surroundings in which they were formerly placed—absence of vegetable food and of light, and absolute tranquillity of water. Their organization then became modified, and adapted itself to these new biological situations; in a word, it became transformed. Phosphorescent organs arose to produce light in the midst of regions that the solar rays no longer reached. Organs of touch were developed, carnivorous characters were substituted for phytophagous ones, and modifications of the mouth were brought about for stealthily seizing large prey that had to satisfy the animal for many days. So submarine explorations have lent arguments of great value to zoologists who assert that animal forms do not constitute those immutable types called species.

It would seem, in fact, when we observe all these surprising animals, that an organism is merely a soft paste in the hands of Nature, which she is incessantly kneading, and the existence of which she perpetuates by adaptations that are continuously renewed during the course of ages.—*H. Filhol, in La Nature.*

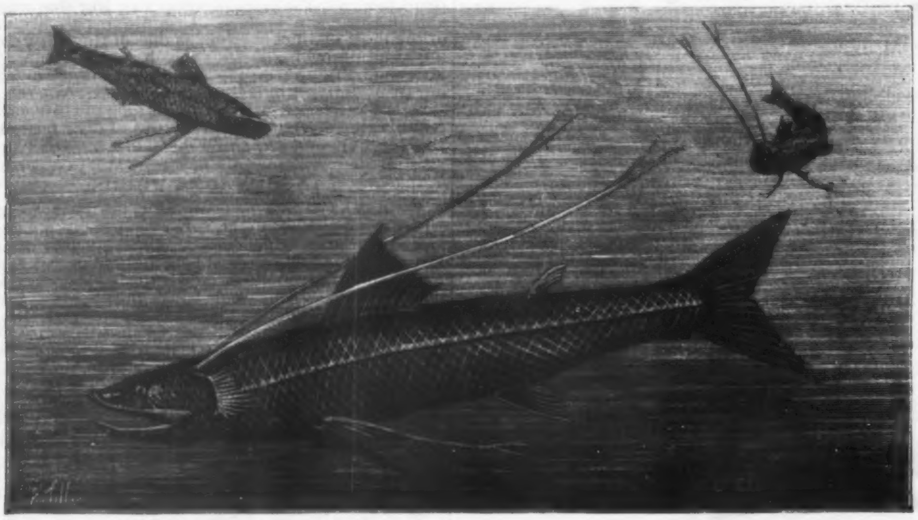


FIG. 1.—BATHYPTEROIS LONGIPES, GUNTH. (Two-thirds Natural Size.)

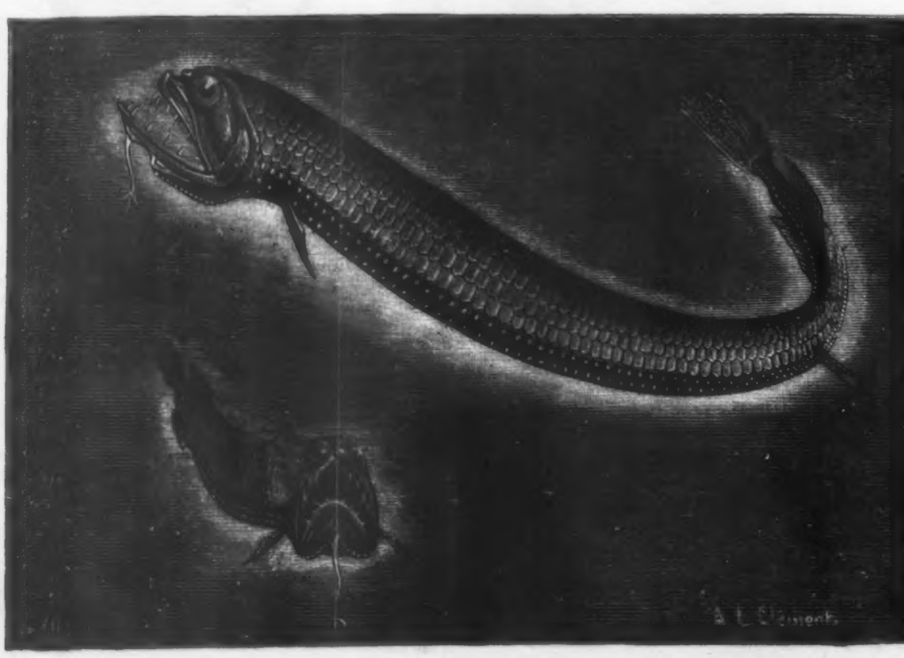


FIG. 2.—STOMIAS BOA, RIS. (One-half Natural Size.)

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TABLE OF CONTENTS.

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